

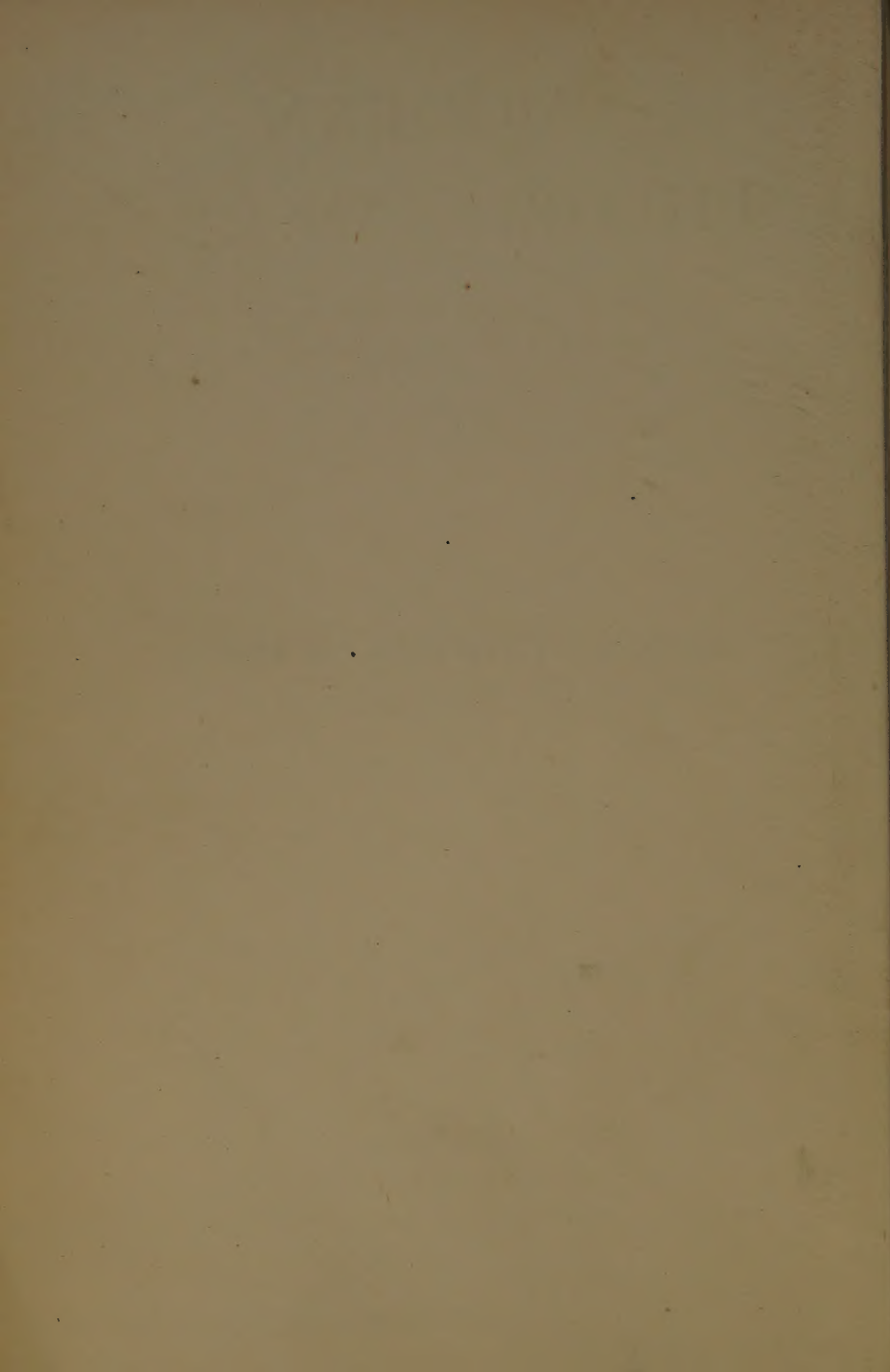
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MODERN THEORIES OF DIET



MODERN THEORIES OF DIET

AND THEIR BEARING UPON
PRACTICAL DIETETICS

BY

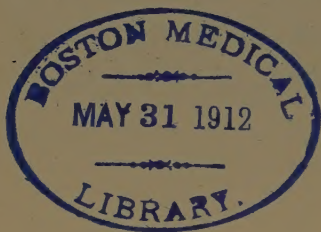
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AUTHOR OF "THE LAWS OF LIFE AND HEALTH," ETC.

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To

RUSSELL H. CHITTENDEN

DIRECTOR OF THE SHEFFIELD SCIENTIFIC SCHOOL OF YALE UNIVERSITY

AS A TRIBUTE TO HIS INVALUABLE SERVICES IN THE ADVANCEMENT

OF THE STUDY OF DIETETICS, AND IN REMEMBRANCE OF

HIS MANY ACTS OF KINDNESS TO THE AUTHOR,

THIS BOOK IS RESPECTFULLY

AND BY PERMISSION

DEDICATED.



PREFACE

THIS is the era of preventive medicine. It is no longer a speciality in the hands of the medical officer of health—it has spread into the domain of private practice. There is an increasing tendency to depend less upon drugs and more upon hygienic methods, less upon therapy of any kind, and more upon such attention to the laws of health as will prevent the inception of disease. Not that the possibilities of curative medicine are by any means exhausted, but that the infinite potentiality of preventive medicine is now being fully recognised.

In no branch of this vast subject has greater advance been made than that of dietetics, until it has now attained such proportions that there are not wanting those who exalt its practice as the only necessity of health. Some have even begun to inquire whether by the adoption of a suitable diet it might not be possible so to improve mankind, by building the bodily edifice of a more enduring and resistant material, as to confer a degree of immunity upon it that would render other branches of preventive medicine ultimately nugatory. I can scarcely subscribe to such a Utopian faith. Nevertheless, I consider the subject of dietetics of incomparable importance, and pregnant with possibility for the future regeneration of the human body. Such a multiplicity of counsellors have, however, appeared on the field seeking for favourable consideration, and the diverse character of their advice is so bewildering, that a full presentation of the subject is necessary for the guidance of those who have not made dietetics their special study.

In the following pages I deal with practically all the important systems of diet which are entitled to serious con-

sideration. Although the book is written primarily for the medical profession, and especially for students of dietetics, it is hoped that it may commend itself to all who are interested in the question, containing as it does little, with the exception of the first two chapters, which cannot be readily understood by any intelligent person.

In the discussion of the various conflicting problems my one object has been to present the truth as it appeared to me. Where I express adverse views to those held by the authors of the different theories, I have endeavoured to couch my opinion in language which, I hope, will commend itself to all for its moderation. Where I have felt it incumbent to express my views more emphatically than usual, it has been more with the view of cautioning the reader than on account of any personal or partisan feeling against the author.

My material has been collected from the most diverse quarters. I have not scorned even to avail myself of the valuable assistance which may sometimes be obtained from laymen, but in every such instance I have supplied a corrigent in the shape of the views expressed by scientific men. This has necessarily entailed much study and correspondence. To all who have been obliging enough to send me information or reprints I hereby acknowledge my indebtedness, although in most instances I have recorded this in the bibliography at the end of the book. Where no such acknowledgment has been made it has been because the reference could not be traced, or because the facts have more or less become part of the general stock of medical information.

I am specially indebted to the editor of the *British Medical Journal* for permission, so willingly granted, to use the following articles contributed by me at various times: "The Limitations of a Purin-free Diet," "A Personal Investigation into the Dietetic Theories of America," "The Limitations of Curdled Milk Therapy."

Here and there throughout the book a sentence or two occurs in quotation marks without any obvious reference. These have been extracted from my recently published volume, "The Laws of Life and Health," and I am under a great debt of obligation to the publisher, Mr. Andrew Melrose, for permission to use them.

Dr. Fraser Harris, Dalhousie Professor of Physiology in the University of Halifax, Nova Scotia, was good enough to revise the first two chapters of "Theories of Metabolism," and I desire here to record my grateful thanks for this service.

Dr. E. P. Cathcart, Lecturer on Physiological Chemistry at the University of Glasgow, very kindly undertook the revision of the whole manuscript at an early stage in its production, and I have taken full advantage of his many invaluable suggestions, emendations, and references to original authorities.

I much appreciate the kindness of Dr. J. H. Kellogg, Superintendent of Battle Creek Sanitarium, the largest vegetarian establishment in the world, who frankly, but temperately, criticised the chapter on "Vegetarianism," and I hope that the information he has placed at my disposal has tended to make that chapter more useful and interesting.

Finally, and in particular, I beg to tender my sincere thanks to Dr. Leonard Hill, Lecturer on Physiology at the London Hospital Medical School, for numerous hints as to the best manner of enlarging the scope of the book, and adapting it more suitably to the purpose of the practical dietist.

I have occasionally considered it expedient to repeat a statement which has found expression in a previous chapter. This has been done advisedly to make the argument more complete.

I shall be amply repaid for the labour involved in writing the book if it will help any one to settle for himself or others the vexed problem of diet.

ALEXANDER BRYCE.

MOSELEY, BIRMINGHAM.

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MODERN THEORIES OF DIET

CHAPTER I

THEORIES OF METABOLISM

INTRODUCTION

NOTHING changes quicker than opinion. This remark may be said to apply truly to every subject, but to none with greater force than that of diet. / We must all eat to live, and one would have thought that by this time such a universal habit would have become quite automatic, or at least encompassed by such stereotyped rules that there was no room for doubt as to its practice.

To some extent, indeed, this statement is true so far as it applies to large sections of people, for custom or national prejudice has ordained that certain alimentary substances should be eaten in a particular manner, so that dietetic habits are formed which appear to have at least a semblance of physiological sanction. But probably for this very reason, and because diet is a question for the individual and not for the nation, its details being regulated more with reference to the temperament than to a fixed standard, there is no general consensus of opinion as to the suitability or otherwise of any system which might with slight variations be made applicable to all. On the contrary, so many theories have of late been presented for our acceptance; that the time is ripe for reviewing the whole situation and endeavouring to arrive at some rational decision which may guide us in the application of dietetic principles in everyday life. For nineteen centuries or more the religious world has attempted

to find a common basis of belief for the conflicting issues before it without avail. But for a much longer period of time it has decided on a common basis of action, which is briefly formulated in the statement that religion is conduct.

In the belief that there is a possibility of determining some such simple rule of action to guide us in the realm of nutrition, I am setting forth, not without some trepidation, to make the attempt.

THE ALIMENTARY PRINCIPLES

In the largest sense of the term, we are what we eat. Food is not only the means of giving us heat and energy, but is the building material from which our bodies are constructed, and by means of which all dilapidations are repaired. A continual process of waste is taking place in the effort to maintain life, and to repair this tissue-waste the intake of material becomes an absolute necessity. Protoplasm is the physical basis of life, and, in addition to its other properties, its essential characteristics are (1) its power of assimilation, *i.e.*, its ability to convert into its own substance nutrient material conveyed to it; (2) its power of excretion, *i.e.*, its ability to expel waste materials produced by its other activities. This exchange of material or intra-molecular rearrangement is termed metabolism, the building up or assimilative process being designated anabolism, the breaking down or disintegrating process receiving the title of katabolism.

In the aggregate, this exchange of material assumes quite considerable proportions, as a healthy full-grown man of, say, 70 kilograms in weight, each day of twenty-four hours—

(1) Excretes about 2,400 grams of water, *i.e.*, 1,300 c.c., by the kidneys, about 600 c.c. by the skin, about 400 c.c. by the lungs, and nearly 100 c.c. by the fæces.

(2) Exhales by the lungs a quantity of carbon dioxide containing about 600 grams of oxygen and from 230 to 260 grams of carbon.

(3) Loses another 20 or 30^g grams of carbon by the fæces and skin, and throws off from 22 to 23 grams of different mineral salts, more than half of which is NaCl.

(4) Eliminates, chiefly in the form of urea in the urine, from 15 to 18 grams of nitrogen.

(5) And dissipates a quantity of energy which, calculated in heat, amounts to 2,400 or more calories.

It can be demonstrated that a certain proportion of this output is derived from the breaking down of the body fat, the muscular and other tissues, and hence a brief consideration of this extensive expenditure will indicate the necessity for the provision of an adequate amount of daily nourishment in the form of food to balance the account.

The elements just mentioned, with hydrogen, constitute, according to Rubner, 95·6 per cent. of the human body, while the other 4·4 per cent. consists of sulphur, phosphorus, silicon, iodine, fluorine, chlorine, sodium, potassium, calcium, magnesium, manganese, lithium, iron, and occasionally others. Few of these occur in the free state. Oxygen and nitrogen (to a slight extent) are found dissolved in the blood-plasma; hydrogen is formed by putrefaction in the alimentary canal. These, however, are exceptions, and it is the rule to find the elements in the body combined with one another to form compounds.

Whilst it is necessary, therefore, to supply all the above elements in order adequately to balance the account, they must be provided in such a form that they can be utilised by the body. The designation applied to the form most suitable for this purpose is "proximate alimentary principles," and these are conveniently grouped as follows:—

ORGANIC.	CARBOHYDRATES.	Non-nitrogenous.
	FATS.	
	Simple organic bodies like the vegetable acids and salts.	
	PROTEINS,	Nitrogenous.
	including products of their decomposition, "purins."	
INORGANIC.	SALTS, or mineral substances.	
	WATER.	

DEFINITION OF FOOD

Although this short classification includes all the food-stuffs, it is nevertheless not an easy matter to formulate a brief yet comprehensive definition of food. This might pass muster: any substance which when introduced into the living organism

will repair the waste of its tissues, and so build them up and furnish it with heat and energy. It might be wise to add that this should be accomplished without causing injury to, or loss of functional activity of, any of its parts. As heat, however important to the economy, is only an indirect product of the combustion of food, perhaps Voit's method of defining a food is preferable: an agreeable and digestible mixture of food-stuffs capable of maintaining the body in an equilibrium, or bringing it into a desired condition, of substance without burdening the organism.

The difficulty experienced in constructing such a definition is in some degree a measure of the extent of our knowledge of the subject, but it is not necessary for my particular purpose to enlarge upon it further than to say that it gives no warrant for the introduction, for example, of elemental nitrogen. I would hardly mention this fact were it not that a few visionary theorists have held it to be capable of extraction from atmospheric air, and so to be utilised for the purposes of nutrition. We may dismiss this theory at once as a pure freak of the imagination, although less exception can be taken to those who claim the admission as a food of elemental oxygen, an ingredient at least absolutely essential to the metabolism of the body.

In considering the theories of diet, it will be found that although there is general agreement as to the necessity for the inclusion of all these alimentary principles in the dietary list of every individual, there is the greatest diversity of opinion as to the proportions in which they ought to be consumed to satisfy the nutritive requirements of the body. The standard which up till quite recently has been almost universally and tacitly accepted was that of Carl Voit, and it is interesting to observe that each of the alimentary principles, but more particularly the protein, has been attacked on the ground that too much of it was permitted in this standard diet of Voit. The tendency has been, therefore, in the direction of a diminution, not so much of the total quantity of food required, as of one or other of the ingredients of the diet, with, of course, a corresponding increase in the remainder.

In addition to this, a number of theories, emanating chiefly

from laymen or irregular practitioners, have arisen around what are called food accessories, or with reference to the appropriate manner of preparing, cooking, or eating food, and as there is frequently some glimmering of truth in every emphatic presentation of this kind, it is my purpose to examine some of these, to extract the grain of truth from the chaff of purely fanciful ideas surrounding it.

Before endeavouring to pronounce an opinion as to the whole question, therefore, it will be necessary to endeavour to trace each item of food through all the transformations to which it is subjected by cooking and metabolism until it is finally ejected from the body. As this is a Herculean, and in some respects at present an impossible, task, we shall consider each food principle in turn, giving a short, concise, and, as far as possible, accurate description of its digestion and metabolism before turning to the theories themselves.

THE NUTRITIVE REQUIREMENTS OF THE BODY

We ought, however, first to examine the methods of ascertaining the nutritive requirements of the body. It is important to deal with this matter here, as much of the confusion and uncertainty associated with the problem of diet centres round the question of quantity. Practising physicians will easily confirm this statement, if they will reflect on the answers frequently wrested from their patients during any inquiry instituted on the subject of their daily meals. They are unduly sensitive, and inclined to resent such an investigation, sparing no pains to produce the impression that they subsist on absurdly small quantities of food. Obviously, the amount of food will vary according to the age and size of the individual, the amount of work he performs, the external temperature and other less important factors, such as idiosyncrasy. It is futile and misleading to make comparisons between the diet of an eight-stone man and a twelve-stone man, without taking all the above factors into consideration.

It is convenient to classify the methods under two headings, (1) Scientific, (2) Empirical; the former being again capable of subdivision into chemical and dynamical.

I. THE SCIENTIFIC METHODS

(1) *Chemical*.—The object of nutrition is to balance the waste and repair of the body. If, therefore, we can estimate the precise amount of waste matter, calculated as nitrogen, carbon, and oxygen, it is possible to draw up a table of the dietetic requirements of the body for its maintenance in a condition of nutritive equilibrium. For all practical purposes it is sufficient to consider only the nitrogen and carbon of the food and excreta, and a balance-sheet of profit and loss may be constructed on these data. A condition of nitrogen equilibrium is established ideally when as much nitrogen is excreted as is ingested, and, as we shall see later, this is possible with very different quantities of nitrogen. Practically speaking, however, it is usual to regard nitrogen equilibrium as established when the nitrogen intake and output only vary to the extent of a few decigrams. It is usual to estimate only the nitrogen output by fæces and urine, and this would account for a difference of a few decigrams, owing to the loss in the sweat and from the degeneration of epithelial cells, as well as the small amount absorbed by hair and nail growth. The body is said to be in “physiological equilibrium” when on a given diet it neither loses nor gains in weight, and this depends upon the fact that the food intake, as regulated by the appetite, corresponds in the long run to the bodily requirements.

(2) *Dynamical*.—This method of computation, which is now almost universally employed, consists in calculating the amount of potential energy contained in the food, and seeing that it corresponds with the amount of external work transacted, and the amount of heat evolved, for maintaining constant the temperature of the body and warming the breath and other excreta. Each of the alimentary principles, when completely oxidised by being burned in oxygen, gives out an ascertainable quantity of heat. This is known as the thermal or caloric value of the food, and it can be stated per gram of the dry food. The unit employed—called the (large) calorie—is the amount of heat required to raise a kilogram of water through 1° Centigrade. The experiment is conducted in an instrument termed a “bomb” calorimeter, and it is found that—

One gram (or nearly $\frac{1}{35}$ of an ounce of dry protein) = 4.1 Calories.

“ (“ “ fat) = 9.3 “
 “ (“ “ carbohydrate) = 4.1 “

One ounce of dry protein, dry starch, or sugar, produces 116 calories of heat, whilst one ounce of pure fat produces 263 calories, almost two and a quarter times as much as either protein or carbohydrate.

From these data it is quite easy to ascertain a factor by the use of which the calorific value of any food may be determined when its percentage composition is known. When this is stated in grams the calculation is extremely simple and no factor is required. It is only essential when the percentage composition is expressed in ounces. For protein and carbohydrates the factor is 1.16, and for fats it is 2.63. All that is necessary is to multiply the percentage value of any given constituent of the diet by the appropriate factor, and thus estimate the number of calories per ounce of each food principle. For example, the percentage composition of cow's milk is 3.5 of protein, 3.7 of fat, and 4.9 of lactose (carbohydrate).

3.5 × 1.16 = 4.07	calories protein	per ounce
3.7 × 2.63 = 9.73	“ fat	“ “
4.9 × 1.16 = 5.68	“ carbohydrate	“ “
Total ... 19.48	“	“ “

or about 400 calories per pint.

In a similar manner bread will be found to possess 9.3 calories protein, 3.7 calories fat, 63.4 calories carbohydrate, or a total of 76.4 calories per ounce. Butter contains 1.2 calories protein, 226.6 calories fat, and no carbohydrate, a total of 227.8 calories per ounce; moderately fat beef will total 25 calories protein and 32 calories fat per ounce, equal to 812 calories per pound. Conversely, to determine the percentage composition of a food when its caloric value is known, divide its caloric value by the appropriate factor.

CALORIMETRY

As all energy set free in the body, except in so far as energy of work is transferred outwards, leaves the body as heat, it is

easy, by computing the amount of heat lost, to furnish a statement of the calories of food required to make good the loss. This can be effected by means of the respiration calorimeter, a chamber in which a man may live from one day or less to two weeks, and by which the output of carbon dioxide, water and energy, and also the intake of oxygen, can be accurately studied. The total heat output of individuals of different size, age, sex and degree of bodily activity is thus easily measured, and the amount of work performed can be controlled with precision by means of a stationary bicycle with variable friction. Such instruments are now in existence in various countries, but perhaps the most satisfactory examples are to be found in the Nutrition Laboratory, Boston, Massachusetts, a branch of the Carnegie Institute of Washington. During a recent visit I examined two splendid specimens which had been constructed under the personal supervision of the Director, Dr. Francis G. Benedict, whose great experience in the science of calorimetry is so well-known, and who hopes by building three more shortly to complete the equipment of a laboratory to be entirely devoted to the study of nutrition. I make special mention of this institution because for years to come its work is to be confined to the study of the production of energy in man and the lower animals, and because, so far as my experience goes, its apparatus is the most complete and comprehensive in existence. Estimations of all the three modes of calorimetry which have been practised in the past, viz., the Pettenkofer-Voit method, the Zuntz and the Jaquet methods, can be accomplished by its use. Whatever the future may hold in store, however, in this direction, it will never suffice to efface the memory of the brilliant calorimetric researches of Rubner, to whom we are indebted for the mean "physiological combustion values" just detailed, and who established the fact that the law of the conservation of energy obtains also in the human organism.

FOOD AND THE SKIN AREA

As one of the most important functions of food is the maintenance of animal heat, it can easily be demonstrated that the amount of food required is directly proportional to the superficial area of the skin. Rubner formulated the law

that metabolism is proportional to the superficial area of an animal, or, in other words, that it depends upon the amount of heat lost at the surface. The means for the regulation of the temperature of the body are twofold: (1) external cold stimulates an increased production of heat; (2) heat is lost from the surface of the body by a variation in the calibre of the cutaneous blood-vessels, and probably in addition an increase in the evaporation of water. Warming the food ingested and the air inspired, and the losses through the heating of the urine and fæces, are factors of very little significance compared with radiation and conduction in the manner just mentioned, and in a less degree by evaporation of water from the lungs and skin. Of the total amount of heat lost by the body, the skin is approximately responsible for 87·5 per cent., the lungs for 10·7 per cent., and the excreta for 1·8 per cent.

The larger the superficies of the body relative to its bulk, the greater is the amount of heat lost by radiation, and the greater in proportion is the metabolism. An infant manufactures 90 calories per kilogram in twenty-four hours, whereas an adult produces only 32 calories. It is obvious that an increase in the food is necessary to engender the extra quantity of heat, and herein lies the explanation of the apparent paradox, that a thin man eats more food than a fat man and yet is not always successful in losing his thinness. When two objects have the same bulk, yet different superficial areas, the one with the greater superficial area will lose the greater quantity of heat, and therefore a greater quantity of fuel must be supplied to it in order that both may possess the same temperature. When two objects differ in bulk, the smaller of the two will part with a greater quantity of heat in proportion to its bulk, and therefore will require a proportionately greater quantity of fuel to enable it to maintain its temperature at the same height as the other.

For this reason it has been found possible to estimate the amount of food required by knowing the amount of skin surface. Children and small people have a much larger skin surface in proportion to their weight than adults or larger people. A child of 10 lbs. weight has a skin superficies of 3 square feet, whereas a man weighing 200 lbs., or twenty times as much, has a skin area of 21 square feet, only seven

times as much. A child of 10 lbs. weight, therefore, requires one-seventh as much food as a man weighing 200 lbs., instead of only one-twentieth as much.

Although of very little value from the point of view of practical dietetics, it is of interest to know that one can calculate the amount of food required by different people of varying sizes, weights, and skin surfaces, by multiplying the weight in pounds by the factor 4.25 and the skin area in feet by the factor 80. The sum of these two products will represent the number of calories per day required to balance the loss sustained by the dissipation of heat from the body and the loss of energy expended in vital work. If the subject is doing severe muscular work, then the factor 7 should be used instead of 4.25.

Tables have been constructed showing at a glance the normal height, weight, superficial areas and number of food units or calories required daily in people of both sexes and at all ages, but they are more interesting than practical. It is of more importance to know that a child under two requires three-tenths of the quantity of food of a man doing moderate work; a child from ten to thirteen three-fifths, and a boy of fifteen four-fifths the amount of food of an average man.

II. THE EMPIRICAL METHODS

The empirical methods are not nearly so satisfactory, although they may under certain circumstances yield very accurate results. Much knowledge may be acquired from the statistics published by the financial department of the Government, but this is necessarily very inexact. It is much better to institute an active dietary study, either where full liberty is accorded in the selection of the diet, or in establishments where definite restrictions are placed upon the quantity or quality of the food consumed. Or, better still, deliberate feeding experiments may be contrived for testing the amounts of the various food substances required by different classes of people and the energy evolved thereby, as the true food requirements of the body are not likely to be ascertained with any degree of accuracy by observations of what people are in the habit of eating, and the customs and habits are not a safe

index of the true physiological needs. Many researches of this character have been undertaken, and the general conclusion has been arrived at that in every case, where possible, the tendency was to indulge in liberal quantities of food, which were increased in direct proportion to the amount of work done. The fuel value of the food varied from 6,000 calories for excessively hard workers to about 2,000 calories for those employed in sedentary occupations.

These results are of immense importance when we reflect that the body absorbs the nutrients from food in certain proportions, no matter how much food has been consumed, although the proteins and fats of vegetable foods are less easily digested and absorbed than those of animal foods. This is probably entirely owing to the different forms in which they occur, the former being enclosed in a stout covering of cellulose, although one is justified in assuming that the more nearly the structure of a protein in the food approximates to that of the proteins of the body, the more chance it has of being absorbed with little or no change. It has been calculated that 97 per cent. of the protein in animal foods is absorbed, as against 84 per cent. of vegetable protein, and that in a mixed diet containing both kinds about 95 per cent. of the total protein is digested. Roughly speaking, 95 per cent. of the ingested fats is absorbed and 98 per cent. of carbohydrates, and these proportions appear to hold good even although excessive quantities of food are indulged in.

THE VOIT STANDARD DIET

It might be considered, therefore, that the total quantity of food consumed, less about 10 per cent. for loss of incompletely oxidised products by the fæces and urine, would represent the nutritive requirements of the body. But upon reflection it will be observed that allowance must be made for the storing up of any assimilated material in the form of fat or other substance which has been in excess of the demands of the body for the immediate production of energy. It was on evidence such as this that Moleschott, Voit, and Atwater determined their various dietary standards. For many years that which held the field, and probably is not yet displaced,

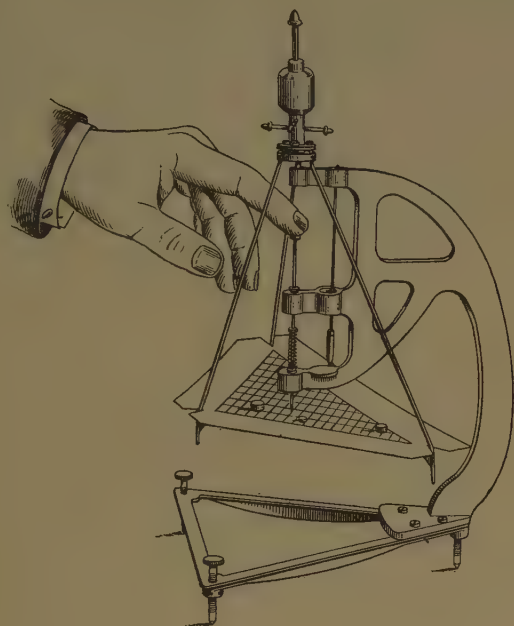
was Voit's, giving 118 grams protein, 56 grams dry fat, 500 grams carbohydrate. This may be considered, therefore, the average quantity of food which it is held that the average man ought to eat, and I give it prominence here because of the necessity for fixing some standard for comparison in connection with the alternative proposals to be referred to in subsequent chapters.

A CALORIC CALCULATOR

It is only in quite recent years that an effort has been made to introduce a means for quickly estimating the amount of food eaten at meal-times, and this suggestion we owe to Irving Fisher, Professor of Political Economy in Yale University. He conceived the idea of having every item on the menu served in definite quantities termed "portions," one "portion" representing 100 calories, and every "serving" (or as we should call it "helping") consisting of one "portion" or a part thereof. This principle is in vogue at Battle Creek Sanitarium, Michigan, U.S.A., where the menu is carefully constructed to show in detail the number of ounces in an ordinary serving, the number of calories of protein, fat and carbohydrates in each "portion," and the number of "portions" in a serving. It is thus a perfectly simple matter for a patient or guest to select from the menu and from the list of articles there tabulated and permitted by his physician the accurate quantity of food measured in calories and also in ounces which he is suffered to consume. I noticed whilst in residence at Battle Creek that many of my table companions were quite indifferent as to the quantity of their food, and simply consulted their taste on the matter, whereas the efforts of some to make their respective items fit into the caloric values prescribed were at times disconcerting, and by no means favourable to the development of a good appetite. I concluded, as one would anticipate, that the proper measure of one's digestive capacity was the appetite, although the experience gained at such an institution as the above might enable a gourmand safely to restrain an unnatural appetite with the assurance that he was satisfying the full demands of nutrition.

Professor Fisher has constructed a most interesting and

highly ingenious indicator for determining the percentage of the several food principles taken at a meal without the trouble of adding the quantities furnished for the various items composing the meal. The essential feature of the apparatus is a card with a diagram of a right-angled triangle, on which points are located to represent the various foods employed. Through these points pins with heavy heads are made to pierce the



PROFESSOR FISHER'S DIET INDICATOR.

cardboard, the weight of each pin representing one "standard portion" or a half or quarter of a "portion." The ration consumed is easily found by counting the "portions" thus represented, and the percentage of protein, fat, and carbohydrate can be ascertained by suspending the card in the ingenious instrument and obtaining the centre of gravity of all the pins. The invention of such an instrument is a manifestation of the increasing interest in the subject of diet, and in all proba-

bility indicates that a period is not far distant when it may become possible to prescribe our patients' diet with as much accuracy as his medicines.

We are now in a position to commence our study of the digestion and metabolism of each of the alimentary principles, in an endeavour to trace the building material of the body through its various stages of preparation and disintegration into the simplest molecules, until each one takes its place in its appropriate position in the edifice. It is only in this way that we can hope to estimate at their true value the various theories about to be submitted, or be in a position to deliver any accurate judgment upon them. As the information at our disposal on this subject is now very extensive, we must content ourselves with the barest summary of the facts compatible with a satisfactory presentation of the position.

CARBOHYDRATES

Although carbohydrates are usually defined as compounds of carbon, hydrogen, and oxygen, the last two elements being in the proportion in which they occur in water, other substances, such as acetic acid, lactic acid, and inosite exist, which answer to this description and yet are not carbohydrates. Chemically speaking, carbohydrates are really aldehydes or ketones (aldoses or ketoses) of polyhydric alcohols, and are probably built up by combination of a number of molecules of formaldehyde— C_2HO . Those derived from hexatomic alcohols are divided into three groups:—

I. *Monosaccharoses* (or monosaccharides), $C_6H_{12}O_6$.

- (a) Dextrose, glucose, or grape sugar, found in fruits, honey, and to the extent of 0.12 per cent. in the blood, as well as other parts of the body.
- (b) Lævulose, often called fructose.
- (c) Galactose.

II. *Disaccharoses* (or disaccharides), $C_{12}H_{22}O_4$.

- (a) Saccharose, or cane sugar.
- (b) Lactose, or milk sugar.
- (c) Maltose, or malt sugar.

III. *Polysaccharoses* (or polysaccharides), $C_6H_{10}O_5n$.

(a) Starch.

(b) Dextrin and its varieties, erythro-dextrin and achroö-dextrin.

(c) Glycogen, or animal starch, found in liver, muscle, white blood corpuscles and other tissues.

(d) Cellulose.

Comparing these groups side by side after equalisation of their carbon atoms, their relationship is seen at a glance:—

Monosaccharoses	...	...	...	$C_{12}H_{24}O_{12}$
Disaccharoses	...	...	...	$C_{12}H_{22}O_{11}$
Polysaccharoses	...	...	...	$C_{12}H_{20}O_{10}$

H_2O subtracted from two or more molecules of monosaccharose results in the formation of disaccharose, and the loss of another molecule of water produces a polysaccharose.

Effect of Cooking.—The nutritive ingredients of all vegetables are contained in cells whose bounding wall is cellulose, and even starch grains themselves are composed of concentric envelopes of starch proper, amyllum or granulose, alternating with layers of starch cellulose or farinose. The digestive enzymes have little or no effect upon cellulose, but fortunately the process of cooking causes such a swelling of the contained starch granules that the cellulose envelope is ruptured and the digestive juices are permitted to come into contact with the granulose. (See Chapter XII. for further details.)

Digestion.—The digestion of carbohydrates takes place chiefly in the mouth and small intestine, although from what has been said it will be inferred that only cooked starches have much chance of being acted upon in the mouth. The action of saliva is really twofold: (a) a physical one, moistening, lubricating, and dissolving soluble substances—in particular starch, which is first converted into what is called “soluble starch,” a material only less colloidal than starch itself, although capable of being coloured blue by iodine; (b) chemical, due to the diastatic enzyme ptyalin, which attacks the starch and converts it by hydrolysis into erythro-dextrin, then achroö-dextrin, iso-maltose, and finally maltose. The same action takes place, though more slowly, on glycogen,

and it is best carried out in a neutral medium, a very small amount of acid in particular inhibiting it. Probably this is all the digestive action which takes place in the mouth, although some authorities claim that the saliva is able to convert 1 per cent. of starch into dextrose.

The importance of cooking carbohydrate food will now be manifest. The process of baking converts the starch of flour in varying quantities into dextrin, and careful people continue and extend this action by a prolonged exposure of slices of bread to a toasting procedure, the result being known as zwieback, or, when the soft central portion only is used, pulled bread. It is claimed by the proprietors of a considerable number of breakfast foods composed of wheat, barley, and oats that a similar effect has taken place in these products. But in any case careful mastication and insalivation will convert starch which is not absolutely raw into dextrin, and through the subsequent stages to maltose.

The secretion of saliva is a reflex action, the sight, smell, and taste of food exciting the glosso-pharyngeal and olfactory nerve endings, and so a communication reaches the chorda tympani supplying the submaxillary and sublingual glands and a branch of the glosso-pharyngeal supplying the parotid. Pavlov has demonstrated that there is not a true psychic excitation of saliva in the manner so well known in connection with gastric juice, but that it is more in the nature of a reflex action, a real physical stimulation of nerve endings just mentioned. His experiments further clearly indicate that the physical condition of the food, especially the property of "dryness," has more to do with the secretion of saliva than the nature of the food itself. Raw meat creates in a dog a secretion, but finely powdered dry flesh is at once responsible for an abundant flow. The chewing of fresh, moist bread produces very little secretion, while dry bread causes the saliva to flow in large quantities. Although acids and alkalis stimulate a flow, neither water nor physiological saline solution excites any secretion. Quartz pebbles, if clean, have a negative effect, whereas sand immediately stimulates a flow. The drier and harder the food, the greater the secretion poured out by the mucous glands—*i.e.*, the submaxillary and sublingual—although milk, for which more saliva is poured out than for flesh, forms

a striking exception to this rule. He concludes, therefore, that substances entering the mouth start a secretion of saliva solely because they excite definite physiological sensitivities.

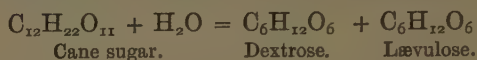
After swallowing, the digestive action of the saliva continues in the fundus of the stomach for quite half an hour or more, until, indeed, the alkali in the saliva is neutralised by the increasing amount of free hydrochloric acid. The presence of 0.1 per cent. HCl in a test-tube terminates its activity, but some time must elapse ere this percentage of HCl can arise in the stomach, and quite an appreciable time after neutralisation has taken place on the outside of the mass of food in the stomach the ptyalin may be quite active in the central portion. It is asserted by some that the ptyalin is not actually destroyed, but only inhibited in the stomach, and Rogers and Simon claim that they have demonstrated that on reaching the duodenum it is reactivated in the presence of the alkaline pancreatic juice. Whatever truth may be in this assertion, it is clear that after neutralisation of the alkali of the saliva no further digestion of the carbohydrates takes place until the duodenum is reached and the amylolytic action of the pancreatic fluid comes into operation. An exception to this statement must, however, be made in favour of the inversion of cane sugar into dextrose and lævulose by the acid of the gastric juice, frequently aided by inverting enzymes contained in the vegetable food which has been swallowed.

Amylopsin—the diastatic ferment of the pancreatic fluid—is its most powerful constituent, acting rapidly on any cooked starch which may have escaped the saliva, and also on the uncooked starch so far as it can reach the latter through its cellulose envelope. This completes the conversion of starch into maltose.

Cellulose is practically indigestible; at least no enzyme has yet been discovered in man which is capable of attacking it, although in the lower animals cytase exerts a hydrolytic action upon it. Still, in man bacterial action in the colon in some cases exercises an influence in effecting its disintegration, although fortunately in most cases it is left intact to accomplish its function of regulating intestinal movement.

The sole object of carbohydrate digestion is to convert the more complex members of the series into one of the mono

saccharoses, viz., glucose, the form most favourable for absorption. We have now, therefore, a mixture probably of maltose, cane sugar, lactose, and lævulose. The cane sugar is next attacked by the invertase of the succus entericus being split into equal parts of dextrose and lævulose, thus:—



By a similar process lactase converts lactose into dextrose and galactose, and maltase acts on the maltose, converting it into two molecules of dextrose. Pavlov states that lactase is always present in the young of mammalian animals, not in those of other species, and that it is absent in adult mammals unless milk-sugar be added to the dietary, when by some special adaptive function the economy acquires the power of producing this ferment. A great deal of doubt has, however, been cast upon the possibility of this specialisation of function, and Aders Plimmer, amongst others, has proved that neither the pancreas nor the intestines of animals can be made to adapt themselves to any particular diet. We have already noted that in the case of the saliva the texture more than the composition of the food is the determining factor in producing the secretory response.

Thus by hydrolysis all the starches and sugars, at least those containing six carbon atoms, termed the hexoses, which alone we have been considering, are converted into monosaccharoses. Other forms of sugar with varying carbon atoms are in existence, but the only group of practical importance are the pentoses, which are in a great measure excreted unchanged in the urine.

Metabolism.—Absorption of the carbohydrate food reduced to the condition of monosaccharoses takes place by the portal capillaries, and in this way being carried by the blood stream to the liver, it is there converted into glycogen. There is hardly any room for doubt as to the various transformations of the carbohydrates up to this point, but our troubles begin here, for we are confronted with two theories as to their further disposal. Before dealing with these in detail, however, it will be profitable to make a few preliminary observations. Chemical analysis demonstrates that blood contains a reduc-

ing sugar, but on account of the extreme difficulty of the process, there is no agreement as to its precise quantity. It is generally stated to be from .05 to .2 per cent., and any increase upon the upper limit is held to constitute hyperglycæmia: its natural consequence, glycosuria, invariably following. The kidneys are impervious to the passage of a certain percentage of sugar, and it is maintained by some that any glucose above .1 per cent. is excreted in the urine. If this is admitted, then the term hyperglycæmia ought to be applied to blood containing .2 per cent. of glucose, and estimating its total volume as 5,000 c.c., quite 5 grams of sugar above the normal would be present. Taking the higher limit as normal, the whole volume of blood would only account for 10 grams or thereby of sugar.

During fasting, portal blood contains the same quantity of sugar as systemic blood, but during absorption from the intestine the percentage is much higher, viz., from .2 to .4 per cent. The liver contains about 10 per cent. of glycogen, and as it weighs about 1,500 grams, that would represent an absorption of 150 grams of sugar from the blood. The amount of glycogen in the muscles is about 1 per cent., and in the aggregate the total content of all the muscular system would be about another 150 grams. This alone would account for something like 300 grams of glycogen, but as it also occurs in the pancreas, the small digestive glands, the lungs, brain, skin, &c., the total amount in the body must be somewhat greater than this.

Although glycogen is found in the white blood corpuscles, yet none has been discovered in the blood plasma, and as in normal circumstances the percentage of glucose in the systemic blood is much lower than that in the portal system, the absorbed carbohydrate food is in the liver converted into glycogen, where it is stored up in the extra-nuclear portions of the cells. Chemically speaking, the transformation of a monosaccharose into glycogen is a simple process, involving only anhydration, but it is really a little more complex than this, as more than two molecules of a monosaccharose ($C_6H_{12}O_5$) must enter into combination, with the loss of one molecule of water for every molecule of monosaccharose, to form glycogen, $(C_6H_{10}O_5)_n$.

All carbohydrates yielding dextrin and l  vulose contribute to the formation of glycogen. Lactose does not, because in the adult there is no digestive ferment capable of hydrolysing it. Subcutaneous injections of cane sugar and lactose do not increase glycogen formation, nor can they be reduced in the blood. Hence there can be no inverting enzymes there capable of forming dextrose and l  vulose from them, and they are excreted unchanged in the urine. Maltose, on the other hand, when injected into the blood increases glycogen formation, because it is inverted into dextrose. It may be concluded, therefore, that dextrose, l  vulose, and possibly galactose, all sugars fermentable by yeast, are the only sugars from which glycogen can be formed. The monosaccharoses, therefore, are absorbed as such, maintain their identity in the portal circulation, and on reaching the liver are changed into glycogen. It may be noted that dextrose is an aldose, *i.e.*, contains the radicle CHO, and l  vulose a ketose, with the radicle CO, and as they are incapable of being converted into each other, in all probability they are transformed into glycogen by a different kind of process.

Bernard's Theory.—The classical view of the glycogenic function of the liver originated by Bernard maintains that glycogen is a reserve store of carbohydrate material for the future needs of the body analogous to the storing-up of starch in the vegetable world. Bernard sustained the doctrine that all the sugar in the portal blood beyond .2 per cent. becomes glycogen, and whenever the content of systemic blood tends to fall below .2 per cent. of glucose it is at once reinforced by a special conversion of hepatic glycogen into sugar, a process which we now know is effected through the medium of an enzyme designated glycogenase. He contended that the percentage of sugar in the blood of the hepatic vein is always greater than that in the portal vein, even when there is no absorption of food from the bowel, and that the blood going to the muscles contained more sugar than that returning from the muscles. He noted that immediately after death a maximum of glycogen and a minimum of glucose were to be found in the liver, whereas several hours thereafter a maximum of glucose and a minimum of glycogen were to be obtained. He considered, therefore, that glycogen leaves the

liver as glucose and is conveyed by the blood to the muscles where it is utilised.

Pavy's Theory.—The other view owes its origin to Pavy, who assents to the doctrine that glycogen is derived from the excess of sugar in the portal vein, but that once formed it is never again in normal circumstances reconverted into sugar, in which form he maintains that it would be at once excreted by the kidney. On the other hand, he contends that the glycogen or carbohydrate molecule is in the liver tacked on to the protein molecule, and thus conveyed to the tissues safely without fear of excretion by the kidneys. He utilises the sidechain theory,* and considers that the carbohydrate molecule attaches itself to a haptophore group, and so being carried to the tissues, is there dissociated for utilisation.

He declares this is proved by the hyperglycæmia in diabetes not being in proportion to the glycosuria. When the sugar is not incorporated with the protein molecules of the living cells, then it appears in the blood, is expelled by the urine, and diabetes takes place. Even if it be locked up properly in association with the protein molecule it may not be oxidised by the tissues, and in the same way diabetes ensues. He maintains that if the liver be frozen immediately after death so as to destroy the glycolytic ferment, analysis will show the percentage of sugar to be higher than in any of the other parts of the body. His theory, indeed, is tantamount to an assertion that the carbohydrate material is converted into fat and protein, which are then metabolised in the usual manner.

Although the classical view retains the field, careful reflec-

* Ehrlich regards living cells as possessed of constitutions analogous to the ring of the benzene molecule, to which as a central nucleus outlying molecules termed sidechains or receptors are attached. These are supposed to subserve the nutrition of the cells by combining with food molecules, oxygen, &c., circulating in the blood. There are several varieties of receptors: (1) Single haptophore (*i.e.*, combining) groups enabling food molecules to become anchored to the cell; (2) those consisting of two groups, one haptophore and the other digestive; (3) those with two haptophore groups, to one of which the food molecule anchors itself, while the other attracts molecules possessed of digestive properties. There are thus specific receptors for the different varieties of protein in the blood, and as an explanation of the method whereby the cells assimilate food and normal tissue nutrition is carried on, this theory is illuminating, feasible, and probably represents the true state of affairs,

tion will reveal the fact that we cannot afford heedlessly to discard Pavy's view. It has been proved that glycogen can be formed probably from all proteins, but certainly from those which contain a carbohydrate molecule, and it is indeed found in animals which consume no carbohydrate food. It is known also from feeding experiments that next to fat, carbohydrates are the most powerful fat producers, and that in diabetes both fat and protein contribute to the manufacture of sugar. On a diet restricted entirely to protein 2.8 parts of dextrose to one part of nitrogen appear in the urine. The diet also contains much more carbohydrate food than would account for 300 grams of glycogen, and the excess, therefore, can only be utilised in the formation of fat and protein.

Accepting the view that glucose is carried by the blood stream to the muscles for oxidation, there are grounds for believing, although no direct proof has ever been offered, that the preliminary stage in this process is a reconversion into glycogen. In any case no glycolytic ferment has been discovered in the blood, and it is not at all probable that any exists there, as hardly any change takes place in its content of glucose even some hours after it has been drawn. Even the muscles in which the actual combustion takes place are apparently devoid of any such enzyme, as expressed muscle juice has no glycolytic effect. As excision of the pancreas is always attended by cessation of the destruction of dextrose, one would hope to be successful in discovering such a ferment in that organ, but neither pancreatic extract nor expressed pancreatic juice can produce glycolytic changes. Cohnheim, however, has demonstrated that a mixture of muscle juice and expressed pancreatic juice possesses marked glycolytic power; and hence it is assumed that the enzyme in the muscle is ineffective until it has been activated by something in the nature of an internal secretion from the pancreas.

In the presence of oxygen the final stage in the decomposition of carbohydrate food takes place, carbon dioxide and water being formed. When glycolysis occurs anaërobically, there is first a formation of alcohol and subsequently of lactic and β oxybutyric acids, each of these substances being produced by its appropriate ferment.

From what has been said we may infer that glycosuria

may be occasioned either by over-production of dextrose in the liver or a want of destruction of dextrose in the tissues.

The former hypothesis is unlikely, as we should expect to find that when all the glycogen of the liver had been decomposed, sugar would cease to be formed, and after death none would be discovered. But we know that in diabetes sugar persists in the urine until the moment of death, and can be found in the liver after death. The existence of alimentary glycosuria must not, however, be forgotten. Some forms of this condition may be due to the loss of the glycogenic function of the liver, but it is quite possible to occur in health from an overfilling of the glycogenic reservoir, due to the saturation of the system with soluble carbohydrates. The assimilation limit of milk sugar is only 50 grams, so that lactosuria is easily produced, but cane sugar and lævulose may be found in the urine after excessive ingestion of these substances.

The latter hypothesis is generally accepted as the etiological factor in the production of diabetes, the body cells being capable of making but an imperfect use of the sugar. This applies particularly to the muscle cells, probably because, as has been already hinted, they have lost the power of first converting into glycogen the glucose presented to them by the blood stream. In any case the respiratory quotient, *i.e.*, the relation of carbon dioxide excreted to oxygen inhaled, which amounts in carbohydrates to 1 as nearly as possible, is in diabetes only about $\cdot 7$, the factor for protein and fat, and that even when dextrose is supplied in the food.

An interesting new conception of the metabolism of carbohydrates which incidentally lends some support to Pavy's theory is that enunciated by Benjamin Moore. He points out that no sugar is present in blood corpuscles, but asserts that it exists in the serum in some form of feeble union with the proteins. If a stream of carbonic oxide be passed through a sample of blood, and this be then subjected to dialysis, the amount of sugar passing into the dialysate is considerably increased above the amount in the case of blood not so treated. As a stream of air to remove the carbonic oxide restores the sugar yield in the dialysate to the normal amount, it is clear

that the sugar must exist in a condition of adsorption with the protein.

In hyperglycæmia, therefore, there is an excess of sugar above that which is capable of entering into union with the protein, and it is this excess which is seized upon and thrown out into the urine by the kidney cells. Sugar appears in the urine of a living animal compelled to breathe air containing more than a certain percentage of carbon dioxide, even although it may contain a greater proportion of oxygen than the normal. As much as 11 per cent. of sugar is found in the urine of dogs subjected to prolonged ether anæsthesia. In the liver cells there is union between the bioplasm and the sugar before glycogen is formed. Glycogen, up to a certain maximum limit at which it separates as granules, can also exist in union in the cells, because it can by appropriate measures be separated from hepatic tissue long before granules appear. It has been found that glycogen injected subcutaneously does not appear in the urine, whereas dextrin does, which might indicate that glycogen was absorbed as such by the muscles, whereas the dextrin could not be utilised, as the blood contains no dextrinase. However that may be, in any case in the normal subject carbohydrates are katabolised into carbon dioxide and water, which are excreted by the lungs, the kidneys, and the skin.

In all probability the first stage in this process is the replacement of two hydrogen atoms of dextrose ($C_6H_{12}O_6$) by one of oxygen, thus forming glycuronic acid ($C_6H_{10}O_7$), a substance usually found in diabetic urine. This oxidation is a simple matter, very different to the later stages, which involve a splitting up of the linked carbon atoms, and probably this is the rôle of the internal secretions of the pancreas.

FATS

Their Digestion and Assimilation.—Fats exist in large quantities in the body in three situations, viz., bone marrow, adipose tissue, and milk. Body fat is a mixture of the three fats, stearin, palmitin, and olein, and its melting-point is $25^{\circ}C$. For this reason the contents of the fat cells of the adipose tissue are fluid during life, and this is due to the low solidification

point of olein, viz. 5°C. , that of palmitin being 45°C. and of stearin from 53 to 65°C. Fats are compounds of fatty acids and glycerine, and are, in the body, under the influence of enzymes, split up into the substances out of which they are built up. The fatty acids involved are oleic, stearic, and palmitic; the two last belonging to the series of normal saturated fatty acids, $\text{C}_n\text{H}_{2n}\text{O}_2$.

Effect of Cooking.—The fats contained in food do not appear to be much affected by heat, although upon cooking they are decidedly more granular than before. Probably this is occasioned by the evaporation of some contained water making the fat more brittle, and distinctly more digestible. Hence the preference of people with a weak digestion for cold boiled bacon.

Digestion.—Except for the melting of solid fat, and the solution of the surrounding protein envelope in the stomach, there is no digestive action on fat worth mentioning until the bowel is reached. It is a point of some clinical interest to note that, amongst the digestive secretions, gastric juice alone is capable of digesting raw connective tissue, so that even in uncooked meat the fatty globules are set free in the stomach. No doubt a minute quantity of fat is broken up into its constituent fatty acid and glycerine in the stomach, because lipase is found there, although its action is somewhat inhibited by the hydrochloric acid. Doubtless much of this lipolytic action is produced by regurgitation of the contents of the duodenum mixed with the pancreatic juice.

On their reaching the small intestine, however, lipase (the lipolytic or fat-splitting enzyme) of the pancreatic fluid causes neutral fats to take up a molecule of water and split up into glycerine and fatty acid, while at the same time, under further influence of the pancreatic fluid, a large part of the fats is formed into a fine permanent emulsion. Doubtless lipase, or steapsin, as it was called formerly, does not exist as such, but in the form of a zymogen which is activated by the bile. The fatty acids liberated are partly saponified by the alkali of the pancreatic and intestinal juices. As in the case of the proteins and carbohydrates, it is believed that bacteria are also in operation producing similar results, and carry the process still further in the stage of fatty acids. Fats have a decidedly

restraining influence on the gastric secretion, and Boldyrieff has discovered that under appropriate conditions, chiefly when acid secretion has been repressed to a minimum by the ingestion of fats, regurgitation of the duodenal contents may take place into the stomach. In these circumstances it is possible to obtain samples of the pancreatic fluid by Einhorn's bucket.

The absorption of fats is much aided by the bile in which the saponified fats are soluble, the bile contributing alkali for saponification from the sodium of its disintegrated salts. In addition it facilitates the passage of the fatty particles through the intestinal wall. Fleig has demonstrated that soluble soaps also act on the mucous membrane of the bowel to produce sapokrinin, a substance which stimulates the pancreas in much the same way as secretin. The soaps pass partly into the lacteals and partly through the capillaries into the blood, although the direct absorption of fat by the intestinal capillaries is doubtful. The fatty acids and glycerine are absorbed by the epithelial cells of the villus and then enter the lacteals, being by that time re-formed into neutral fats. Altogether about 95 per cent. of the fat in the diet is absorbed, although when consumed in large pieces not more than 84 per cent. may be utilised. The lower the melting-point of fat the greater quantity of it is absorbed. Thus only 2.3 per cent. of olive oil is recoverable in the fæces, whereas 9.2 per cent. of mutton fat, and as much as 90 per cent. of stearin remain unabsorbed.

Metabolism.—As with the carbohydrates, there is much conjecture as to the final disposal of fat by the tissues. Pavy declares that carbohydrates are converted into fats in the villi, and this is not at all incredible, as in plants they are mutually interchangeable. In experiments on rabbits he could see the villi full of small particles after feeding with oats, and this he thinks could hardly be due to the 5 per cent. of contained fat. Although fat is quite easily oxidised by living cells, the tissues are not inclined to treat it quite so kindly as they do the protein, *i.e.*, by embracing it; for whenever it is presented in excess of heat requirements it is deposited in the subperitoneal, subcutaneous, and inter-muscular spaces as adipose tissue, with a composition very similar to that of the fat consumed. Thus the adiposity produced by mutton fat is more lasting and firmer than that produced by cod-liver oil, and therefore when

fat is presented in an easily assimilable form, *e.g.*, in hot milk, it is much more valuable for phthisical patients than fat of a less soluble order.

The storing up of fat is to prevent physical bankruptcy. When it is required it is again broken down, doubtless by the tissue-enzyme lipase, into fatty acids and glycerine, and so utilised for the production of energy. Just how this takes place is quite unknown, although various hypotheses have been constructed to account for it. Carbohydrates can be theoretically conceived as being converted into fat by the loss of carbon dioxide and water, provided a large number of carbohydrate molecules be assumed to be transformed to produce only one molecule of fat. It has, of course, been proved experimentally that carbohydrate in the body is converted into fat, and this has been stated to take place even when the supplies are not excessive. Feeding experiments on pigs, dogs, cows and sheep with food freed as much as possible from fat and albumin, but very rich in carbohydrate, are attended by an increase of the adipose tissue, much more fat being deposited than could have been accounted for by the fat and albumin in the food. The carbon excreted in the expired air and the urine was infinitely less than that contained in the carbohydrate food, so that large stores were being retained in the body. Carbohydrates possess a much greater amount of oxygen than fats, and it may be that in the combustion of the former part of the sugar carbon completely saturated with oxygen is excreted as carbon dioxide, and the remaining carbon compounds, being now poorer in oxygen, unite to form fatty acids. It is calculated that 100 grams of grape sugar ought to yield 37 grams of fat.

Moore mentions that Bainbridge and Leathes by partial interference with the blood supply have been able to make the liver cells take on the appearance of fatty degeneration, the cells becoming loaded with obvious fat globules. The appearance presented is as if the fat had enormously increased in quantity, but analysis reveals no increase. Normal liver tissue can contain from 5 to 10 per cent. of fat without displaying the slightest appearance of fatty material, and this must therefore be an integral part of the bioplasm. It must, in other words, be linked on to the protein by the process of

adsorption, because a much smaller quantity of fat in the free form would present itself as a thick emulsion. Union of a similar loose character must take place in the blood serum, for from a perfectly clear serum showing no oil globules under the microscope from .5 to 1.0 per cent. may be extracted by alcohol and ether, an amount sufficient to show itself as an emulsion. After a heavy fatty meal the serum looks quite milky, but this disappears in an hour or two, being all taken into union by the liver bioplasm and other tissue cells. This is undoubtedly the explanation of fat transference from tissue to tissue without any appearance of emulsification, and in the same way fats are oxidised without any globules of fat being in evidence.

In any case, like the carbohydrates, the end-products of the fats are carbon dioxide and water, which are excreted by the skin, kidneys, and lungs.

PROTEINS

Their Digestion and Assimilation.—The proteins are highly complex compounds containing—in addition to the carbon, hydrogen, and oxygen, which we have seen are the elements constituting fats and carbohydrates—nitrogen and sulphur. They may be divided into the following classes, beginning with the simplest:—

(1) The protamines in the roe and milt of fishes, the only proteins not known to contain sulphur.

(2) The histones in blood corpuscles.

(3) The albumins in blood serum, egg and milk (soluble in water alone).

(4) The globulins in blood and white of egg (soluble in water with the aid of a neutral alkali salt).

(5) The sclero-proteins, *e.g.*, collagen of connective tissue, gelatin, keratin, elastin, ossein, chondrin.

(6) The phospho-proteins, *e.g.*, vitellin in egg-yolk, caseinogen of milk.

(7) The conjugated proteins:—

(a) Nucleo-proteins, combinations of protein with nucleic acid, which on decomposition yield purins.

(b) Gluco-proteins, *e.g.*, mucin, combinations of protein with carbohydrates. The carbohydrate substance is not always sugar, but usually a nitrogenous substance called glucosamine, with a similar reducing power to sugar and a similar formula to glucose, HO being replaced by NH_2 , thus: $\text{C}_6\text{H}_{11}\text{O}_5\text{NH}_2$.

(c) Chromo-proteins, *e.g.*, hæmoglobin, combinations of protein with chromogenic compounds.

(8) The derivatives of the proteins, produced by hydrolysis, as in digestion and otherwise, are usually considered to form another class by themselves. These are:—

(a) Metaproteins.

(b) Proteoses.

(c) Peptones.

(d) Polypeptides.

(e) Amino-acids.

This classification refers almost entirely to animal proteins. The vegetable proteins are really in a class by themselves, for although many of them may be ranged under the above headings—leucosin in wheat being an albumin, and edestin in hemp a globulin—the glutelins and gliadins are quite distinctive. The glutenin of wheat gluten is an example of the former class, and, like its associates, is insoluble in water but soluble in dilute alkali; the gliadins differ from all other proteins in being soluble in alcohol alone, in containing no lysine amongst their cleavage products, and in yielding a very high percentage of glutamic acid, although all the vegetable proteins give a much higher yield of this amino-acid than any of the animal proteins.

Effects of Cooking.—As with other food-stuffs, the application of heat exercises a mechanical as well as a chemical action. The former is manifested in the case of meat, *e.g.*, chiefly by the formation of steam between the fibres, which tends to loosen them and render them more accessible to the digestive juices. The insoluble collagen of the connective tissue is converted into soluble gelatin, the protein of meat is coagulated, and odorous substances (extractives) are developed, which impart flavour and stimulate the appetite. Although the proteins are rendered more insoluble by cooking, it is

undeniable that the process is on the whole favourable to digestion, because of its concomitant counterbalancing advantages.

Digestion—(a) *Gastric*.—Protein digestion begins in the stomach and is effected by the hydrochloric acid and pepsin of the gastric secretion. Like most other enzymes, pepsin has its precursor in the form of pepsinogen, which is inactive until it comes into contact with an acid, the most effective compound being pepsin-hydrochloric acid. Pavlov has demonstrated that this secretion occurs in two stages: (1) the psychic or “appetite” juice, which begins before food is partaken of and which has always the same composition, whatever the food of the last meal may have been, and (2) the chemical juice, which is modified to suit the character of the food, bread exciting the most concentrated juice, meat the most acid juice, milk the least acid of all. Edkins has shown that the contact of certain food substances with the pyloric end of the stomach originates a certain chemical product, a gastric hormone, gastrin as he calls it, which is absorbed into the circulation and acts as a powerful stimulus to the further production of gastric secretion. The flow of chemical juice cannot be excited by all forms of nutritious substances, for white of egg and starch have no effect, and, as we have seen, fats actually diminish the flow. The most potent of all the excitants of gastrin are hardly to be classed as nutrients at all, viz., the extractives of meat; but by increasing the flow of chemical juice they contribute greatly to the digestion of the food and materially assist the appetite. Kobert has also shown that they remove the effects of muscular fatigue. When albumoses and peptones are likewise present, as in many forms of meat extract, they may be nutritious, although unfortunately, by containing “purins,” they have for many people the defects of their qualities. Other substances of a similar character are dextrins, dextrose, maltose—chiefly the products of the salivary digestion of carbohydrates—and to a slight extent milk and water. Vegetable “bitters” have no influence *per se* on the flow of gastric juice: their mere contact with the mucous membrane of the stomach does not assist digestion, as is proved by taking them in a capsule; their sole effect is a reflex one, originating in the mouth.

Thus gastric juice begins to flow before food reaches the stomach, goes on increasing for an hour or so, and then begins to decline. Mendel has proved that the stimulation of the gastric glands may take place without direct gastric irritation, in consequence of the influence of alcohol absorbed from the intestine, a fact which goes far to explain some of the hyper-acidity of the dyspeptic and the dipsomaniac. Two of Mendel's pupils have likewise demonstrated that other substances, *e.g.*, oil of peppermint, induce a similar secretion, and have attributed this result to a reflex act, although it might as well have been occasioned by its absorption and direct stimulation of the gastric glands from the circulatory side. We are well aware that morphia and iron are thus excreted by the stomach and bowel wall, even when introduced parenterically, and there are now many observations to show that other substances, *e.g.*, calcium and phosphorus, are excreted by the intestinal mucous membrane. This is important, as it is now recognised that "biliousness" may be due to excretion from the gastric mucous membrane, and that a diseased appendix may excite vomiting either in the same way or through reflex influence.

In the stomach proteins are converted by the pepsin-hydrochloric acid into peptones, and this takes place in various stages. Firstly, the combination with hydrochloric acid produces acid meta-protein, formerly called syntonin, or acid-albumin; then proteoses or propeptones, including albumoses, globuloses, vitelloses, elastoses, and gelatoses, are formed. All these are precipitated by nitric acid; but peptones, which are the next step in the process, are not, and although soluble in water are not coagulated by heat. If the action of digestion is sufficiently prolonged, further cleavage products arise, called polypeptides, which are probably combinations of amino-acids, and at length the individual amino-acids appear, this stage, however, not usually taking place in the stomach, but after the chyme has passed into the small intestine.

The greater the amount of protein, the longer the time will elapse before free hydrochloric acid appears. This is of importance, because until the free acid reaches a certain degree of concentration, the pylorus will remain closed, and the contents of the stomach cannot begin to pass into the duo-

denum. The moment the pylorus under this impulse relaxes, a certain portion of the acid gastric contents gushes out into the duodenum, and the pylorus then contracts. Contact of this acid chyme with the duodenal mucous membrane stimulates its pro-secretin-containing cells to produce secretin; and Bayliss and Starling have demonstrated that this is absorbed into the blood current, and through this medium travels to the pancreas and liver directly, stimulating them to pour out pancreatic fluid and bile respectively. Doubtless, besides this direct chemical excitant or hormonal effort, reflex action plays its part in the process.

(b) *Intestinal*.—The pancreatic fluid contains an inactive zymogen called trypsinogen, which by means of the enterokinase of the succus entericus is converted to trypsin. This is a strongly proteolytic ferment which resembles, but acts much more rapidly than, pepsin in an alkaline medium, so that alkali-meta-protein is the first product formed. It also acts much more powerfully on certain proteins, such as elastin, although it cannot digest collagen, whereas raw connective tissue can be digested by the gastric juice. There are other minor differences; but the most important point to be noted is that protein digestion is carried much further by trypsin than pepsin, polypeptides and amino-acids always being formed.

The succus entericus is also probably secreted through excitation by hormones. Cohnheim proved that it contains erepsin, a peptolytic enzyme which attacks the proteoses and peptones produced by trypsin and pepsin, and forms from them their final cleavage products, the amino-acids, thus assisting the action of trypsin. Apparently the only native protein which it digests is caseinogen.

Besides the enzyme activities which we have just described, there is a coincident action of the bacteria. This does not usually arise in the stomach, because of the antiseptic effect of the gastric juice, but originates quite high up in the small intestine, and may take place in two ways: firstly, by the production of enzymes, which act in the same way as the pancreatic juice; and, secondly, by fermentation and putrefaction, due to the organisms themselves. The effects on the proteins depend largely on their relative position in the alimentary canal. In the open air, *e.g.*, indol rapidly makes

its appearance, and shortly thereafter phenols betray their presence, especially if the reaction is alkaline—an example of a toxin being followed by its appropriate antitoxin. Precisely the same thing happens in the bowel, and not only amino-acids but members of the aromatic and fatty series quickly arise. The lower end of the small intestine frequently has an acid reaction, and if this be continued into the colon, less putrefaction is likely to arise and the risks of auto-intoxication are diminished. So long as bacterial action is not excessive it is an aid to the pancreatic juice and successful in decomposing poisonous products which might be absorbed. Choline—*e.g.*, a derivative of lecithin, found in large quantities in egg-yolk—is decidedly poisonous, but is usually broken up into carbonic acid, methane, and ammonia by bacterial enzymes.

Operations of a parallel character on fats and carbohydrates are performed by bacteria, acid products being formed from them by lactic, butyric, and even alcoholic fermentation.

Thus the end-products of protein digestion are proteoses, peptones, amino-acids, and ammonia and salts of ammonium, which in the liver are synthesised to urea.

Absorption.—So far there is little possibility of dispute; but now we reach the realm of theory, and there is much contention as to the future course of events. Kuhne's view of protein digestion and absorption was that hemi-peptones and anti-peptones were formed, the former being absorbed, the latter giving rise to leucin, tyrosin, and other amino-acids not capable of absorption, being therefore wasted.

But we know that there are many kinds of proteins. Osborne has discovered quite twenty in wheat alone; and we know that they are split up by hydrolysis into at least twenty different amino-acids, amongst which are leucin, tyrosin, glycocoll, cystin, arginin, tryptophane, and histidine. As we have seen, this decomposition occurs in successive stages from complex to simple, and it would be interesting, if it would not take up too much time, to study the probable method of formation of each.

Probably the simplest example of an amino-acid is glycocoll or glycine, which is practically a fatty acid, *viz.*, acetic acid, CH_3COOH , with one of the three hydrogen atoms in the CH_3 ,

group replaced by the amino-group NH_2 , forming amino-acetic acid or glycine, $\text{CH}_2\text{NH}_2\text{COOH}$.

Alanine is amino-propionic acid, propionic acid being the next number of the fatty acid series. An extremely complex specimen is tryptophane, a near relation of the last mentioned. It is indol-amino-propionic acid, and is the parent substance of two foul-smelling products of protein decomposition called indol and skatol. Amino-acids are divided into two classes according as they contain one or two amino groups, hence called mono-amino-acids and di-amino-acids respectively, and the former is still further subdivided into three groups.

Had this information been at the command of the earlier physiologists, fewer mistakes would have been committed in connection with the metabolism of proteins. Even now it is a moot point what happens to the spilt-up products of protein digestion. Kuhne's view, which has been just mentioned, is obviously incorrect, because it is known that peptones injected into the blood act as reducers of blood pressure, producing collapse from toxæmia and subsequent peptonuria. To combat this difficulty it was assumed that intestinal products of digestion are dehydrated by the epithelial cells of the bowel-wall into blood-plasma proteins, and on this was constructed the "circulating protein" theory of Voit, which stated that the serum albumin and globulin were the ultimate forms of protein nourishment for the living cells. Hofmeister's view was that peptone was absorbed by intestinal lymphocytes, and in this bound-up condition traversed the circulatory system without filtering through the kidneys—an obvious parallel to Pavy's theory.

It is now taught by some that the amino-acids are absorbed by the intestinal epithelium, and there reconstructed into the proteins of the blood, these again being disintegrated by the cells of the tissue, and from these ultimate products the specific proteins of the tissues are formed. Others, again, maintain that there is no immediate re-synthesis, but that after absorption the products are presented in turn to the different tissues, which are thus permitted to make a selection according to their requirements.

Future chemists will doubtless be able to trace the complex protein molecule right down to its simplest ultimate fragments,

and demonstrate the manner in which they are utilised in the construction of each individual tissue, but despite the brilliant results of Emil Fischer's labours we have made little progress towards the elucidation of this problem.

Autolysis.—It is well known that the tissues themselves contain specific enzymes, some of which have been isolated, and which are responsible for autolysis in appropriate conditions. It is also known that the blood proteins are not food for cells, because during starvation they undergo practically no diminution, and in any case are not sufficient to account for the continued energy put out by the tissues. Voit has pointed out that during starvation the "noble tissues," the brain, central nervous system, and the heart, literally live on the less "noble tissues," fat, muscle, and connective tissue, and considers that there is therefore a strong presumption that nutrition in starvation is by amides and amino-acids derived from the organs autolysed and carried to organs which can synthesise these katabolites into tissue proteins. Miescher showed that the Rhine salmon, which does not feed in fresh water, nourishes its reproductive organs at the expense of its muscles. There is thus evidence for the existence of two forms of enzyme in the tissues, one protein-disintegrative, the other protein-integrative in action, although it is possible that it might be the same enzyme, and thus be an example of "reversible zymolysis." Loewi fed dogs on the abiuret products of the autolysis of the pancreas, *i.e.*, on soluble crystalline substances which give no biuret reaction at all, and, with of course the addition of fat and carbohydrates, found that they remained in nitrogenous equilibrium. Henriques and Hansen demonstrated that this would not take place if hydrochloric acid were used instead of the autolytic or tryptic enzymes, and they suggested that the acid uncouples some linkages which the ferment does not.

Besides this, there is a denitrifying enzyme at work in the intestinal mucosa which splits off the amido group as NH_3 , and this, sent to the liver by the portal blood, is transformed into urea and so excreted by the kidneys. There is a great increase of NH_3 in the portal blood during the absorption of protein food. When, therefore, the nitrogen molecule has been dissociated from the non-nitrogenous or carbonaceous molecule,

this latter is, in the shape of fatty acids, oxy-acids, or thio-acids, passed to the tissues and is used for the production of energy. The relation of nitrogen to carbon in the protein molecule is as 16 : 52, *i.e.*, 1 : 3.25. Leathes believes that quite 90 per cent. of the carbon of the protein is metabolised in unions which are non-nitrogenous. Protein, therefore, is dealt with in two distinct ways according as its nitrogenous molecule or its carbonaceous molecule is required. In the former case the nitrogen goes to the tissues for building up and repair purposes; in the latter, the nitrogen is excreted as urea.

CHAPTER II

THEORIES OF METABOLISM—*continued*

Theories of Protein Metabolism.—Before the formulation of the theory which I shall presently indicate, and which is generally accepted as correct, three important hypotheses had existed.

(1) *Liebig's*.—This scientist maintained that protein is the sole source of muscular work, the carbohydrates and fats being the sources of heat, and that the economy must obtain all protein in a preformed condition, as being unable to synthesise it from simple crystalline products. This view was shattered by the experiment of Fick and Wislicenus, who in the ascent of the Faulhorn in 1865 subsisted solely on non-nitrogenous food, and found that the nitrogen excreted indicated a metabolism of protein quite insufficient to have produced anything like the energy represented by the work done in their climb.

(2) *Pfluger's*.—He held that all the nitrogen excreted as urea had been during the previous twenty-four hours an integral part of the living tissues, and that it had been derived from the food previously absorbed. In other words, all the protein katabolised had been first formed into bioplasm, and was then by a process of oxidation converted into urea even during overfeeding with meat.

(3) *Voit's*.—This consists in the statement that the protein of the absorbed food passes to the living tissues, and is there katabolised without first becoming an integral portion of the latter. Thus the living tissue which consists of "organised" protein is bathed or suspended in a solution of "circulating protein," and the chemical decompositions that constitute protein katabolism take place only in solution.

It is hardly conceivable on the one hand how the extremely large quantities of food protein which are known to be katabolised in the twenty-four hours could have been built up into the tissues and as rapidly burned away, or, on the other, just how the proteins in the blood could definitely reach all the tissues of the body and come into contact with them without becoming an integral portion of their substance.

The whole subject has been recently most carefully reviewed by Folin, who points out that no fundamental theory concerning protein metabolism can be accepted unless it can be made to harmonise with the laws governing the composition of the urine. Now, "normal urine," as understood by the text-books, is that urine excreted after feeding on the diet usually known as the Voit standard diet. The whole misconception as to metabolism and certain dietetic theories reared thereupon are due to the tacit acceptance of Voit's standard of 118 grams of protein, which most authors and scientists have copied without taking the trouble to verify. They have even persisted in doing this after it was demonstrated that nitrogenous equilibrium was possible on one-third of the protein of the above standard. Folin, therefore, made a study of human urines obtained from diets as different as possible from the so-called standards of diet—some being vegetarian, some purely carbohydrate, &c.

In this study he elicited the fact that the composition of urine representing 15 grams of nitrogen, *i.e.*, 95 grams of protein, differs very widely from the composition of urine representing 3 or 4 grams of nitrogen, *i.e.*, 25 grams of protein, and that there is a gradual and regular transition from one to the other. To explain such variations he thinks that we must assume that there are two forms of protein katabolism essentially independent, and quite different—the one variable in quantity, the other constant. The former chiefly yields urea and inorganic sulphates, no creatinin, and probably no neutral sulphur. The latter or constant katabolism is largely represented by creatinin and neutral sulphur, and to a less extent by uric acid and ethereal sulphates.

The fact that creatinin elimination is not diminished when practically no protein is administered with the food, and that the elimination of some of the other constituents is only

slightly reduced under such conditions, explains why a certain amount of protein must be furnished with the food if nitrogen equilibrium is to be maintained. The metabolic processes resulting in the end-products which tend to be constant in quantity appear to be indispensable for the continuation of life, and this he calls tissue or endogenous metabolism. The other or variable protein metabolism he calls exogenous or intermediate.

The key to endogenous metabolism is the elimination and physiological significance of creatinin: and in addition to the researches of Folin much work has been done on this subject by Mendel and his pupils. The facts elicited may thus be summarised. Plants contain no creatin or creatinin, but these substances are found in the tissues, especially the muscles, of all vertebrate animals. Hence there must be endogenous and exogenous creatinin elimination. Creatinin is excreted in the urine during starvation in patients on a vegetarian diet, and is always a constant quantity, different for different individuals, but quite independent of the total amount of nitrogen eliminated. It varies with the weight of the individual, and muscular persons excrete a greater proportion than those inclined to adiposity, proving that bulk of muscle is a factor in the amount excreted. The most abundant extractive of muscle is creatin, which is closely allied to creatinin, the latter being formed by dehydration of the former. It is assumed, therefore, that in normal metabolism creatin is continually produced and converted into creatinin, and that this is rapidly eliminated. Besides creatin probably urea and water in small quantities are formed in the muscles, and if it were known just how much urea—if any—was formed from the same katabolic processes that form creatin, then endogenous metabolism could be more definitely estimated.

CREATININ, THE MEASURE OF ENDOGENOUS PROTEIN METABOLISM

Despite this latter statement, creatinin may be taken as the measure of the antecedent tissue—or endogenous metabolism, and urea of the exogenous metabolism. Much experimental work must yet be undertaken to determine accurately the precise qualitative excretions of endogenous metabolism, and

it is possible this exact estimation may never be completed, as it is so difficult to separate the two kinds of metabolism. If it were possible to make this calculation, then the answer to the question as to the necessity for this exogenous protein metabolism would be imminent. It is quite clear that enough protein to maintain endogenous protein metabolism is indispensable.

It has been assumed that the entire katabolism of protein takes place in the same tissues, *i.e.*, chiefly the muscles, by oxidation in a similar manner to the fats and carbohydrates. But this is erroneous, as no oxidation is necessary for the decomposition of proteins, hydrolysis being sufficient. For this reason it is unnecessary to assume that all the katabolic processes take place in the muscles. Urea, the chief nitrogenous substance excreted in exogenous metabolism, is only found in extremely small quantities in muscle. On the other hand, creatin, the chief extractive of muscle, cannot be converted into urea either there or in the liver, but is eliminated as creatinin.

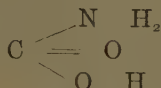
It is proper to add that the formation of creatinin is still a subject of great controversy, but, as will be more fully indicated in a later chapter, in all possibility the liver is responsible for its production. Creatin injected into the blood stream does not contribute to the formation of urea, but is excreted unchanged. Nor is there the slightest proof that the creatinin of the urine is derived from the muscular creatin. On the other hand, it is a fact of some significance that in diseases of the liver creatinin is excreted in diminished amount. It is conjectured that certain products of protein katabolism are carried to the liver, there transformed into creatinin, which is transported to the muscles as creatin. When the muscular store is complete the excess of creatinin is excreted by the kidneys. With a mixed diet from .8 grams to 1.2 grams of creatinin are excreted daily; with a vegetable diet, somewhat less, .6 to .86 grams.

It is perfectly evident from what has been said that by far the greater portion of the urea appearing in the urine is not formed in the muscles. We know that outside the body urea very quickly decomposes into carbonic acid and ammonia, to both of which substances it is very closely related. It is

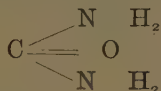
indeed the diamide of carbonic acid, as will be obvious from a study of its chemical composition.



is carbonic acid. Replace one of the hydroxyl groups by an amide group, and we get



which is carbamic acid, and by a repetition of the process we get



which is carbamide or urea. On the other hand, ammonium carbonate is easily converted into ammonium carbamate by the loss of a molecule of water, and by the loss of another molecule of water becomes carbamide or urea.

Now we have already seen that in protein digestion a certain amount of ammonia is formed, and we know that ammonia is produced in the organism from amino-acids. We also know from feeding experiments on rabbits and dogs that the body possesses the power of creating urea from ammonia and most of its salts, especially the carbonate, citrate, formate, and lactate, although the chloride, phosphate, and sulphate of ammonium are exceptions to this rule.

That the liver is the seat of this urea formation is considered a certainty from the following facts. In the first place urea ceases to be excreted in the urine and is replaced by ammonia when the liver is removed from frogs. A similar operation cannot be performed in mammals because of its fatality, but on establishing Eck's fistula in the dog, whereby the blood of the portal vein is divided from the liver and passed directly into the vena cava, the amount of urea diminishes from about 90 to 77 per cent., and its place is taken by ammonia. In certain diseases of the liver, *e.g.*, acute yellow atrophy, the urea

practically disappears from the urine, whilst ammonia and the amino-acids, leucin and tyrosin, are present. Now we know that these originate in the intestine and on absorption pass through the liver, where they are usually converted into urea. Finally the blood in the portal vein is known to contain a larger quantity—nearly three times the amount—of ammonia than that in the hepatic vein, and by injecting defibrinated blood containing ammonium carbonate Schröder was able to obtain urea in abundance from the hepatic vein, no other organ in the body giving a similar result. It is therefore clear that exogenous nitrogen may become converted into urea without going near the muscles.

We also know that there is a limit to the growth of muscle in man, as only during the period of youth and convalescence, or to a certain extent during a holiday or severe physical exertion, is there any addition to the muscular system. A large quantity of food protein is not therefore required for building new tissues, because after attaining full growth the daily wear and tear of the tissues is small.

Yet we have seen that practically all the protein consumed is digested and absorbed, and if it be not used for building purposes, for what other purpose can it be destined? Now, it has always been assumed that the tissues use protein in preference to fats and carbohydrates, because the bioplasm has a large nitrogen content. If this be the case, then it follows that the more protein we swallow the better, a conclusion to which even high-protein advocates would not give their assent.

UREA, THE MEASURE OF EXOGENOUS PROTEIN METABOLISM

The greater the amount of protein that is ingested, the greater will be the amount of urea excreted, and so we are forced to the conclusion that the body can break up the protein molecule and discharge its nitrogenous moiety in order to obtain the use of the carbonaceous portion for the production of energy.

The organism cannot freely store up protein, and this is an explanation of nitrogenous equilibrium being able to be maintained on varying quantities of protein food. As Folin says, "The ordinary food of the average man contains more

nitrogen than the organism can use, and increasing the nitrogen still further will therefore necessarily only lead to an immediate increase in the elimination of urea, and does not increase the protein katabolism involved in the creatinin formation any more than does an increased supply of fats and carbohydrates."

The normal body can store fats and carbohydrates, and their katabolism consists chiefly of oxidations setting free heat to keep up the temperature or to appear as mechanical work. The removal of nitrogen from protein by deamidisation sets free very little heat or energy, but yields a non-nitrogenous portion of great value, capable of oxidation if required. When not used in this manner it is probably converted in part into carbohydrates or stored up as fat. It is notable that large eaters of meat are usually corpulent, and after a certain age are apt to become glycosuric.

Thus we have true tissue or endogenous katabolism with creatinin as its index, and exogenous katabolism—a splitting-up of the excess of food protein with the elimination of unnecessary nitrogen by deamidisation and the formation of a carbonaceous moiety later on—with urea as its index.

It is rather difficult to assess the relative proportions of exogenous and endogenous katabolism, but with an intake of 100 grams protein quite three-quarters will be excreted as urea and not more than one-quarter will represent true tissue katabolism.

It is also difficult to say which of the amino-acids are utilised for tissue formation and which of them are broken down into urea. Injection of glycine, leucin, and arginin directly into the blood stream is followed by an increased formation of urea, whereas in a similar experiment with tyrosin and phenyl-alanine a negative result ensues. It is, therefore, conjectured that these two last mentioned amino-acids are examples of building stones which actually take their place in the growth and renewal of the bodily tissues.

As we have just stated, an extremely difficult point to decide is what quantity of tissue protein undergoes decomposition and requires renewal each day. Muscular exercise has very little influence on the excretion of urea, while it enormously increases the expiration of carbon dioxide, indi-

cating that muscular energy is dependent on the combustion of non-nitrogenous material, and it is believed more particularly of carbohydrate. When an insufficiency of carbohydrate and fat is supplied to the muscles, or when an excess of work is done, they are then compelled to fall back on their protein contents for the production of energy.

The principal end-products of the katabolism of proteins in the body besides urea and creatinin are carbonic acid, water, and sulphuric acid (in combination as sulphates).

Purin Metabolism.—In consideration of the fact that many foods and food accessories such as tea, coffee, cocoa, contain certain purin bodies, it is important that we should endeavour to trace them through their various manifestations in the body. One of the most important changes to which purin bodies are subjected is oxidation, and their highest product of oxidation is uric acid. This is a complex compound form from which two molecules of urea can easily be split off, and may be looked upon as a combination of urea and an acid containing three atoms of carbon. The acid best answering this description is acrylic acid, and it is interesting to know that from the chemical point of view it is a close relative of lactic acid—hydracrylic acid being an isomer of lactic acid—and that Horbaczewski has synthesised uric acid from tri-chlorolactic acid and urea, and also by heating urea and glycocoll together.

In reptiles and birds the greater part of the nitrogen leaves the body as uric acid, but this never obtains in mammals, where only a small proportion—about 3 per cent.—of the nitrogen ingested appears in the urine as uric acid, while quite 86 per cent. is excreted as urea. Probably the explanation of this difference may be found in its great insolubility, one gram of uric acid requiring at the body temperature seven litres of water for its solution and being only slightly soluble in cold water. For this reason it is discharged in birds and reptiles in the solid form of acid ammonium urate, and no disadvantage is associated with this method of excretion, as in both of those classes of animals the urine is expelled from the ureters into the cloaca by the pressure of the oncoming fæces. Were this to take place in mammals the microscopical uric acid crystals would give rise to excessively painful symptoms. Consequently, it is fortunate that in them

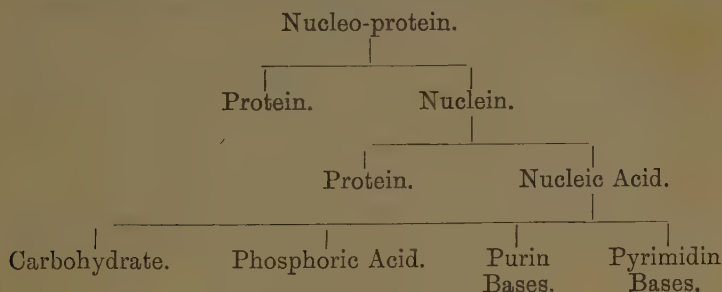
this form of nitrogen is at a minimum in the urine, so that it may be possible to keep it in solution.

In man only .5-1 gram of uric acid is expelled in the twenty-four hours, whereas about 40 grams of urea are excreted in the same time.

The purin bodies are now well known to be derivatives of the nucleo-proteins. These latter are compounds of protein with a phosphorus-containing organic acid called nucleic acid, and are found both in the cytoplasm and the nuclei of the cells.

Nuclein, which is identical with the chromatin of the cell nuclei, contains quite 10 per cent. of phosphorus, and on disintegration forms protein and nucleic acid. The nucleo-protein of the cell protoplasm on the other hand contains only 1 per cent. of phosphorus.

The composition of nucleo-protein will probably be better grasped by the following diagrammatic representation:—



Two forms of nucleic acid have been differentiated.

(1) A pure form, yielding on decomposition—

- (a) A carbohydrate of the hexose group,
- (b) Phosphoric acid,
- (c) Two purin bases—adenin and guanin,
- (d) Three pyrimidin bases—cytosine, uracil, and thymine, the last yielding thyminic acid.

(2) Guanylic acid—a less complex form of nucleic acid, which can be decomposed into:

- (a) A carbohydrate of the pentose group (1. xylose),
- (b) Phosphoric acid,
- (c) Guanin alone.

Uric acid, which is dibasic, never occurs pure in the body, but is always combined with bases as urates—normal sodium urate and acid sodium urate. It is the chief end-product of the katabolism of the cell nuclei, and Emil Fischer has shown that among the products of decomposition of their nuclein, the purin bodies are the most important. In the human body these are always in organic combination and never in the form of salts, but they possess a common nucleus, C_5N_4 . Purin, $C_5H_4N_4$ (or purine), is itself only of theoretical interest, as it has never been discovered in the body.

The other members of the series occurring in foods are:—

Hypoxanthin	...	$C_5H_4N_4O$	...	...	Monoxyypurin	} Purin Bases
Xanthin	...	$C_5H_4N_4O_2$	...	...	Dioxyypurin	
Adenin	...	$C_5H_4N_4NH_2$	...	...	Amino-purin	
Guanin	...	$C_5H_3N_4ONH_2$	...	...	Amino-oxypurin	
Uric Acid	...	$C_5H_4N_4O_3$	...	...	Trioxypurin	

There are many other purin derivatives, but only a few are of importance as occurring in tea, coffee, cocoa. Theophyllin in tea, theobromin in cocoa are dimethyl oxypurins, and caffein in coffee is trimethyl oxypurin. They are, however, more usually classed together as methyl xanthins.

Metabolism of Uric Acid.—In its metabolism uric acid follows laws of its own, quite independent of other nitrogenous compounds. During the digestion of organs containing blood (*e.g.*, spleen, liver, and other glands), xanthin bases originate if air be excluded, whereas if plenty of air be supplied their place is taken by uric acid. This occurs in varying degrees, *e.g.*, from 3 grams of hypoxanthin swallowed by men 62 per cent. of uric acid has been found, while from .6 gram of guanin only traces of uric acid could be discovered in the urine. It is to be noted, however, that it is difficult to transform free guanin into uric acid, but it is easy to do so in the case of the combined guanin of the nucleo-proteins of the pancreas.

The methyl xanthins increase the purin bases of the urine, but are in no way dependent on nuclein metabolism, and do not influence the excretion of uric acid.

The excretion of uric acid bears no relationship to the extent of protein metabolism, for an excessive consumption

of nitrogenous food (free from nuclein) does not increase the amount of uric acid excreted, even although the metabolism may be increased. Thus from 18 grams of protein food 433 mgr. uric acid were excreted, whereas from 80 grams of protein food not more than 442 mgr. uric acid were excreted.

Uric acid is, in fact, chiefly derived from the nucleins, and the proportion of total nitrogen to the uric acid nitrogen is not a fixed quantity, but fluctuates from 25 : 1 to 126 : 1.

Flesh foods contain more uric-acid-forming material than vegetable foods, not only in the form of purin bases but also as free xanthin bodies especially hypoxanthin and xanthin.

For physiological purposes the purins are subdivided into distinct classes, the endogenous and the exogenous. About one-half of the uric acid excreted in the urine comes from the purins set free in the tissues (endogenous) and the other half from the food ingested (exogenous).

(1) **Endogenous Purins.**—These originate from the katabolism of the cell constituents, especially the nuclei. It is also stated that in all probability leucocytes, epithelial cells, &c., are eaten up by phagocytes and so katabolised into carbonic acid, water, and nitrogenous waste products of the nature of purins, chiefly uric acid. But this is hypothetical.

A small proportion of the endogenous purins is produced by muscle metabolism, and the katabolism of nuclein and nucleo-proteins. Mendel has shown that all purins can be resolved into uric acid in the liver, muscles, and to a less extent in the kidneys. Fifty per cent. of this is further oxidised into urea, for which a plentiful supply of oxygen is necessarily provided, of course, by the increased respiration of physical exercise.

Just how much endogenous uric acid is formed it is difficult to say, but each individual has a fairly constant excretion in similar conditions of exercise, &c. There is some reason to believe that the bacillus coli plays a part in the formation of uric acid, and if so, this suggests a possible relationship between a purin-free diet and the absence of auto-intoxication.

Even during starvation the excretion of uric acid does not cease, although it becomes rapidly diminished, and infants fed on milk containing only traces of purin bases may excrete as much as 100 mgr. uric acid daily.

(2) **Exogenous Purins.**—These are simply the same purins as the endogenous, but introduced into the body in the form of food. They exist either in a free or bound condition, the former indicating those in solution, ready prepared or, as it were, mechanically mixed with the tissues; the latter, those in chemical combination with the tissues and unable to be dissolved until chemical decomposition takes place.

They are discovered almost as freely in vegetable as in animal foods, and the following is a fairly complete list of the food-stuffs into whose composition they enter. All animal foods, especially the glandular organs, liver, pancreas, kidney, thyroid, &c. All “beef-teas,” meat soups, and gravies prepared from animal foods, beans, peas, lentils, oatmeal, asparagus, mushrooms, potatoes, sugar-beet; tea, coffee, cocoa (as methyl xanthins); and beer, all contain purin bodies, but in many cases only in minute amounts.

In all these substances they are simply waste products *en route* for excretion which have been arrested in the tissues before being discharged. In the case of vegetables, which possess no excretion except that of a gaseous character, the excretory products are removed from the neighbourhood of vital parts and deposited in such tissues as the bark of trees, the leaves, and the cell walls.

When partaken of by man as food, or rather in combination with food, as they possess no nutrient properties, they are katabolised into much simpler compounds, the terminal product in most instances being uric acid. In this last form or even as less katabolised, they are excreted at a fairly uniform rate, except for a distinct increase during the morning hours. After a meal containing purins, there is a decided increase in the excretion of uric acid, varying with the individual and his diathesis. Thus it is possible for a slight delay in the excretion to occur in the gouty, and this is perfectly certain to occur when any alcohol is consumed at meal-times.

Uric Acid Excretion.—The actual amount of uric acid excreted on a purin free diet varies from .25 gram to .6 gram, and on a mixed diet from .5 gram to 1 gram in the twenty-four hours, and it rises rapidly with the increase of flesh foods or glandular organs in the dietary.

Even after its formation in the body its quantity by no means remains constant, as it is in part further decomposed and much changed before excretion. The various steps in the process of the formation of uric acid from nuclein are of great interest, chiefly on account of the important part played therein by ferments. The first stage is effected by nuclease, which liberates the two purin bases adenin and guanin from the nucleic acid, and these are again attacked by the adenase and guanase forming respectively hypoxanthin and xanthin by the substitution of an oxygen atom for the amino group. These two deamidising enzymes are succeeded by oxidising ferments or oxidases, which convert hypoxanthin into xanthin and xanthin further into uric acid.

The active agent in the disintegration of uric acid is the uricolytic enzyme, which is capable of decomposing quite half of it into urea (and perhaps lactic acid), carbonic acid, and water. It has been estimated that about one half of the hypoxanthin nitrogen, and one quarter of the nuclein purin nitrogen appears in the urine as uric acid, while one third of the caffen nitrogen is excreted as basic purin nitrogen. The liver and spleen contain considerable proportions of these enzymes, and it is more than probable that alcohol destroys or inhibits the action of the uricolytic ferment in the liver. It is indeed possible that inhibition of this ferment may be achieved by other agencies, viz., the sea air and the east wind, both of which have a tendency to cause an increase in the output of uric acid, and undoubtedly exert some malign influence on the liver. Toxins such as tea, coffee, tobacco, &c., may also have the same action.

Three or four years ago Wiechowski declared that no satisfactory proof had been adduced that urea was the end-product of purin metabolism in mammals, but that in man uric acid, and in dogs allantoin, were the excretory products of purin bases. Ackroyd has now in the main confirmed this view so far as dogs are concerned, because by perfusing normal saline through the excised liver, as being the least likely to upset the normal ferment action, he found that a small quantity of allantoin was produced, and that the uric acid was destroyed and partly converted into allantoin, with no indication of urea.

Variable quantities of uric acid are oxidised in different

people at various times, and in every case the uric acid discharged in the urine is only the balance left over from the original amount formed after deduction of the amount destroyed.

Increase of the excretion of uric acid may be due to—

- (1) An increase in the consumption of exogenous purins.
- (2) Increased destruction of the cells in the body.
- (3) Diminished oxidation of uric acid in the body.
- (4) Increased washing out of stores retained in the body.

There is, however, no proof of the retention of uric acid in the body excepting temporarily in gout, although exogenous purins may remain for days in the body.

(5) The possibility of a synthetic formation of uric acid in the body from substances other than nuclein or purins.

As has been already mentioned, uric acid is the terminal product of protein katabolism in birds and reptiles, where it is formed in the liver. Unquestionably in a synthetic manner, urea, strange to say, being its immediate precursor. When the liver in these animals is extirpated or artificially excluded from the circulation, lactate of ammonia is excreted instead. Now we know that during exercise lactic acid is developed in the muscles as a fatigue product, and that many other acids in small amounts, such as carnitic acid, inositic acid, with small quantities of urea and at least three purin bodies—hypoxanthin, xanthin, and uric acid—are to be found. Lactic acid is likewise to be found in the stomach in the early part of digestion, and in large quantities in the alimentary canal in indigestion. We have also seen that protein is broken down into ammonia, and in this way carried to the liver, and so all the elements for the synthetic formation of uric acid would appear to exist. But at any rate in normal circumstances there is not a sufficiency of lactic acid to reach the circulation, and although in abnormal circumstances it may do so, no definite proof exists of this method of formation of uric acid in mammals.

Uric acid, however, is certainly formed in most of the organs of mammals, and some observers declare that the muscles by the oxidation of hypoxanthin are prominent in this action. Spriggs, on the other hand, declares that the source of by far the greater part of the endogenous uric acid is to be looked for in the non-muscular tissues. It is important to remember that

the organs which form it are also capable of destroying it. The ingestion of water has no influence on the formation of uric acid, and but little on its excretion.

It may be established as a principle that purin excretion is fairly constant for any person living under the same physiological conditions. In any individual, however, continued administration of salicylates will cause an increase in the excretion of uric acid, the quantity gradually diminishing day by day for about five days until the effect is lost. As this occurs alike in mixed feeders and purin-free feeders, it may be taken for granted that it is the endogenous uric acid which is thus affected. The increase in the excretion of uric acid may be re-established either by daily increasing the dose of salicylates or ceasing their administration for a couple of days and then resuming the original dose. On the cessation of the salicylates the excretion of uric acid is diminished to a point below the normal. Various explanations have been offered for this action. Some hold that it is due to an actual solution and loss of the uric acid in the tissues; others that it is caused by increased metabolism of the nucleins; while others again declare that it is due to diminished destruction of the endogenous uric acid by inhibition of the uricolytic ferment. Another hypothesis is that the salicylates act as bactericides, preventing, or at least lessening, putrefaction in the colon, and this is interesting in view of the suggested influence of the *bacillus coli* in uric acid formation.

A more recent explanation is that, like all antiseptics, the salicylates produce much irritation of the intestinal mucous membrane, in addition to killing the bacteria, both of which factors militate against the complete breakdown of the proteins to a stage in which they may be absorbed, and hence proteins are excreted with the fæces. This would certainly account for the decidedly laxative properties of salicylates, especially in the form aspirin and novaspirin.

Purin bases chiefly in the form of methyl-xanthins are found in the urine to the extent of about 8 per cent. of the uric acid excreted, and it should be noted that the one cannot be substituted for the other. A large quantity of xanthin bases occur in the fæces from (1) unabsorbed nuclein substance in the food, (2) the nuclein substance of the epithelium separated

from the mucous membrane of the bowel wall in a fashion analogous to the shedding of the epidermis.

The Metabolism of the Mineral Salts.—Excepting in a purely vegetarian diet which requires the administration of a variable quantity of chloride of sodium, there is no necessity for making any special provision for the addition of mineral substances to the menu, as they are so closely associated with the food-stuffs that more than enough is usually obtained with an ordinary mixed diet. During the process of digestion they are, in the first instance at all events, to a great extent separated from the alimentary principles, and then pass through the intestinal capillaries to the liver and the systemic circulation, although a certain proportion, *e.g.*, iron and iodide of potassium, may reach the blood by way of the thoracic duct. On account of the difficulties attending the investigation, it can hardly be wondered that so little is known about the subject, or the ultimate disposition either of water or the soluble salts. We are well aware that the absorption of the one is closely bound up with the absorption of the other, because the result of prolonged research has proved that common salt and the other soluble inorganic salts constitute the osmotic factors in absorption and excretion.

Salt solution (NaCl) unquestionably passes from the bowel into the blood-vessels and lymphatics of the intestinal walls, but just how far the cells themselves as living units are engaged or involved in this process it is impossible to say. A saline solution cannot pass into the capillaries of the bowel by osmosis without displacing something from the blood-vessels. It is quite possible this is one of the factors contributing to the production of the fæces, because it is now well-established that a considerable proportion of the contents of the residue known as “fæces” has been eliminated by the bowel wall. Far too little is known, however, on the subject, and what part is played by diffusion, filtration, and imbibition in addition to osmosis.

Mineral Substances.—The following mineral substances are utilised by the body along with the alimentary principles:—

Chlorides of sodium, potassium and ammonium, phosphates of sodium, potassium and magnesium, carbonates

of sodium and calcium and bicarbonate of sodium, sulphates of sodium and potassium, iron and manganese in small quantities, and silicon and fluorine in still smaller quantities, are also to be found in the body.

Sodium, besides occurring in the combinations just mentioned, may also be found in association with vegetable acids used as food or food adjuncts, and possibly in loose combination with protein. Chloride of sodium, about which we shall have more to say in connection with the salt-free diet, controls osmosis and dissolves globulins. The total quantity contained in a normal body never exceeds 200 grams, and about 15 grams are excreted daily. The carbonates of sodium are to be discovered chiefly in the blood plasma, where they assist in carrying the carbon dioxide from the tissues to the lungs. They are partly formed from the malates, citrates and tartrates in fruits. Sodium salts are sparsely excreted in the fæces, so that most of what is ingested is absorbed, and apparently the capacity of the body for the absorption of sodium salts is unlimited.

Potassium salts have an affinity for the solid tissues, and thus chloride of potassium is to be found in fairly large quantities in the muscles, milk, and red blood corpuscles. The body supply is derived chiefly from vegetable foods, and as these are never all absorbed, potassium salts are always to be found in the fæces.

Calcium salts are to be found in food associated with albumins of acid character, and also in the inorganic forms of phosphate and carbonate. Vegetable foods are richer in calcium than flesh foods, although milk and eggs form an exception to this rule, and drinking water often contains a considerable proportion of lime. For the most part lime salts are excreted by the fæces, usually in the form of phosphates, carbonates, and compounds with the higher fatty acids. From .1 to .5 gram of calcium per day appears in the urine, so that a certain proportion is absorbed, chiefly as phosphates and carbonate, in the upper part of the intestinal canal. Their appearance in the fæces indicates either that they have never been absorbed or, having been so, have been eliminated again by the bowel wall. The greater the quantity of acid contained in the food or produced within the system, the

greater will be the proportion of calcium excreted in the urine. Hence, the consumption of acid fruits in the diet causes an absorption of lime salts into the blood and tissues and their subsequent passage into the urine. Hence, also, the reason why the alkaline urine of vegetarians and herbivora contains so little calcium, whereas that of meat-eaters and the carnivora contains it in greater abundance. It will now be apparent why the urinary calcium is increased in acidosis. Both carbonate and phosphate of calcium are to be found in bone, teeth, and some of the body fluids.

Phosphorus in the body is always to be found as phosphoric acid, either in an organic or inorganic form. Lecithin and nucleo-protein are examples of the former variety, and are probably disintegrated by the digestive juices absorbed as salts of glycerophosphoric acid, 80 per cent. of the phosphoric acid subsequently appearing in the urine and the rest in the fæces. Most of the phosphorus, however, is ingested in the inorganic form, and the amount of the phosphates in the urine depends on the quantity of the calcium, acid, and alkali introduced into the body or already there. Eventually three-fifths of the phosphates are to be found in the urine and the rest in the fæces.

Phosphate of calcium forms one half of the bones and occurs in the dentine and enamel of teeth and in other solids and fluids, *e.g.*, milk.

Phosphates of soda and potassium give the body their alkaline reaction to chemical test, and the sodium-di-hydrogen phosphate is chiefly responsible for the acid reaction of the urine.

Sulphur is absorbed chiefly in organic combination with protein, and is excreted in the urine partly as combined or oxidised sulphur and partly as unoxidised neutral sulphur.

Iron, of which about 3 grams are to be found in the blood, occurs chiefly in food in the inorganic form of hæmoglobin or nucleo-proteins, *e.g.*, the so-called "hæmoglobin" of egg yolk and milk. Green vegetables, *e.g.*, spinach, cabbage, fresh asparagus, wheat, strawberries, cherries, &c., are particularly rich in iron. It is absorbed from the duodenum in organic combination and excreted almost solely in the fæces, the body requiring from 16 to 30 milligrams per day.

The mineral salts yield no energy to the body, at least in a direct form. In contradistinction to the food-stuffs which are only absorbed as required by the body, *i.e.*, in response to a definite demand, the saline substances are absorbed in greater quantities than are required. Little is known as to their definite effect, and speculation is rife as to the manner in which they are dissociated from the food-products in which they are incorporated, brought into solution, carried to the tissues requiring them, and finally broken down and expelled from the body. Bunge has a most novel conception as to the final disposal of the chlorides, which is treated at some length in his well-known book.

BUNGE'S THEORY OF CHLORIDE OF SODIUM EXCRETION

One of the essential constituents of every living cell is potassium, and this element is seized upon by the cells in the quantities necessary for their correct functioning. The fluids of the body, on the other hand, display an affinity for sodium, the plasma of the blood having a special preference for it. Herbivorous animals crave for common salt, whereas carnivorous animals strongly object to it.

Vegetable foods are rich in potassium, in contradistinction to animal foods, which are deficient in it. This liking of the herbivorous animal for common salt is explained by the preponderance of potassium salts in vegetable foods, for when the latter are absorbed into the blood a reaction takes place between them and the common salt there. The double decomposition results in the formation of chloride of potassium and sodium carbonate, which are rapidly ejected by the kidneys, thus depleting the blood of chlorine and sodium. Hence, the final result of the ingestion of vegetable foods is a craving for sodium chloride. It is said to be proved that when a man lives on animal foods he desires no common salt, but the moment he adds the potassium-containing vegetables, his affection for common salt begins, and it is remarkable that this is the only foreign salt which he adds in a chemical form to his food.

Bunge asserts that he has proved his theory by experiment, for he administered in three doses 18 grams of K_2O to a man on a uniform diet, with a consequent loss of 6 grams

NaCl and 2 grams of sodium, the potash salts having effected an exchange not only with chloride of sodium but also with the albuminate, carbonate, and phosphate of sodium. He estimates that if a man lived entirely on a diet of potatoes he would consume 40 grams of potash salts, whereas if he employed rice as his sole diet and took enough to supply him with 100 grams of protein, he would only obtain 1 gram of potash salts. Hence the necessity for eating salt with potatoes.

He considers, however, that vegetarians may be able to live without adding common salt to their dietary, but they would have a very strong disinclination to eat potatoes. Whatever truth there may be in the theoretical part of this argument, however, it is a fact that amongst vegetarians and fruitarians are to be found the strongest supporters of the salt-free diet. In Battle Creek Sanitarium the patients are encouraged to subsist without the addition of salt at the table, and comparatively little is added in the kitchen. It may be that special methods of cooking vegetables rich in potassium salts, *e.g.*, potatoes, beans, peas, &c., are in vogue, but an effort is made to create a fondness for foods like rice, which is almost free from alkaline salts. It is recognised that this entails much less excretory work on the kidneys, and on this point Bunge has shown that on a diet of meat and bread without added salt 6-8 grams of alkaline salts will be excreted in twenty-four hours; on a diet of potatoes and salt, 100 grams will be excreted in the same time; whereas where rice is the staple article of diet only 2 grams of alkaline salts are excreted each day. Chlorine in the body is always to be found in the inorganic form, and probably an average man of 70 kilograms will contain nearer 150 grams than 200. The five litres of blood should account for about 25 grams, while 40 grams will be found in the 35 kilograms of muscles: the fat and bones contain still further smaller proportions.

Chloride of sodium may be withdrawn from the body—

(1) During fasting and underfeeding; *e.g.*, Cetti excreted in ten days of his fast 175 grams.

(2) By the administration of large quantities of the alkaline carbonates or compounds of the alkalis with vegetable acids,

In such circumstances not only chlorides of sodium and potassium, but other acid substances are excreted.

(3) By frequent vomiting or by frequent washing out of the stomach. By this means the alkalinity of the blood can be temporarily raised, but this condition only lasts for a very short time, as the body rapidly absorbs more chlorine.

Chlorine can be replaced in the body by bromine, but not by iodine, and in certain circumstances it is possible to find in the stomach hydrobromic acid instead of the usual hydrochloric acid.

From 3 to 4 grams of phosphoric acid (P_2O_5) are required each day by the body. It differs from chlorine in this respect, that whereas the latter can be retained on occasion, phosphoric acid continues to be excreted even during starvation. When, however, flesh is put on, a certain amount both of nitrogen and phosphoric acid is stored up in the tissues in the definite proportion of $16.7 :: 1$, and a still larger supply is required both for the growth and repair of the bones. A certain amount of organic phosphoric acid is absolutely required by the tissues, although they can very well exist without any inorganic supply.

Lime in the form of carbonate can for a time be stored up in the body in large quantities. For every gram of lime, bone will be found to contain .73 gram P_2O_5 and flesh .137 gram P_2O_5 . Three-quarters of a gram of magnesia (MgO) are required by the body each day.

It is quite certain that mineral salts are of vital importance to the body, as experiments on animals with food depleted of its salts speedily terminate in death. Chittenden holds strong views upon this subject, and this will be again referred to later on, when dealing with his low protein theory, but it may be stated here that he believes that protein pure and simple is unlikely to be utilised as a food in the body except in association with some salt of sodium, potassium, or calcium. The freedom from scurvy when fresh food or lemon-juice is administered is closely associated with this problem of the dietetic necessity for mineral salts.

Wright attributes many troubles to the diminution of calcium in the blood, amongst them chilblains: non-salt-eaters are said to suffer severely from this irritating affection.

On the other hand, the non-salt-eaters contend that this is not so, and that they are never afflicted with eczema, influenza, rheumatism, colds in the head, even when they discard woollen underclothing, and that they gradually regain the faculty for distinguishing the delicate natural flavour of foods. We shall revert to this subject later on.

Mendel and Stanley Benedict have made a series of investigations into the paths of excretion for inorganic salts, and the following are among their conclusions. When soluble magnesium compounds are introduced into animals parenterally (*i.e.*, by other channels than the alimentary canal), the greater portion not absorbed by tissue leaves the body by way of the kidneys in less than forty-eight hours. This is accompanied by a diminished output of calcium by the fæces, and an increased excretion by the kidneys, showing that the calcium content of the blood is increased. It is remarkable that the magnesium introduced in the manner mentioned never causes purgation—contrary to the usually accepted opinion. The body has the power of storing both calcium and magnesium, thus introduced, for a period of several days. The one base is capable of partially replacing the other, although this vicarious action is not sufficient to account for the common prescription of magnesium salts in oxaluria.

The Adsorption Theory.—In connection with the metabolism of mineral salts, an interesting view has been presented by Benjamin Moore. He declares that the living cell from the physio-chemical point of view may be looked upon as a machine through which is passing a constant flow of energy, which is distributed in other forms without the integrity of the cell being to any obvious extent affected. These supplies of energy always come to it in the form of organic compounds capable of being oxidised in the cell substance. For the preservation of this capacity to oxidise, it is essential that its own substance be preserved in an unimpaired state, and this is dependent on the presence of the ions of certain simple inorganic salts in the cell and its surrounding fluid media. If this supply of inorganic ions is not maintained, then the physiological activity of the cell is interfered with much more than if the supply of organic nutritive material be defective,

because the cell can always use those stored up within its own substance or even actually utilise its own substance for this purpose.

If an isolated heart muscle be immersed in a solution of distilled water and dextrose, it will cease to beat instantaneously, but in a solution of NaCl isosmotic with the natural serum of the animal from which it was taken, the beating will persist for some minutes. This isosmotic solution prevents the cells being suddenly disrupted, but cannot continue to preserve the integrity of the heart muscle, because NaCl solution has a zero pressure for certain ions indispensable to the activity of the heart. The ions of potassium and calcium are then slowly diffused out, and the cells are then unable any longer to draw upon their stored up energy, but the addition of $\frac{1}{10000}$ part of KCl and even less Ca to the NaCl solution enables the heart-beat to be continued for hours.

This is an effective demonstration of the labile equilibrium between the colloids of the cell protoplasm and the osmotic pressure or concentrations of the inorganic ions and other crystalloid constituents. If to the above solution of NaCl, KCl and Ca, dextrose be now added, then the heart-beat is prolonged for a much longer period of time.

Bioplasm is composed of an aggregation of the variously constituted protein bodies, loosely combined with fats and carbohydrates and the ions of the inorganic salts, to form a united system. The attachment of these different parts to each other remains constant by varying "the organic oxidisable substance, viz., the protein bodies themselves, the fats and carbohydrates which suffer temporary molecular disruptions, during which the oxygen also held in the bioplasm comes into union with them, and the oxidised products as they increase in pressure are shed off from the cell." Heating with alkalis or acids under pressure causes the proteins to take up the element of water and yield simpler organic compounds, the process known as hydrolysis. On the other hand, by dehydration or condensation, union is effected amongst the organic radicles of the proteins.

These organic radicles are of three classes: (1) purely organic bases, (2) purely organic acids, (3) amino-acids which

possess the properties of both in a modified degree. These last undergo condensation or conjugation with one another, or with other organic bodies, to form long chains in single series, or main chains with side or branch chains arising from them, a process easily effected if we will only remember that many of them contain more than one basic group or more than one acidic group, so that ramification can take place in all three dimensions of space. This goes on until equilibrium is reached between the synthetic or building up and the disrupting forces.

In this process a number of poles of opposite types are left capable of being satisfied with substances of opposite polarity held in loose attachment. This form of union by residual affinities is spoken of as adsorption, and every grade of affinity for union may exist, between the double decomposition which constitutes chemical combination and the physical union of an infinitely weaker type which is entitled adsorption. In this last state stability is only possible so long as a certain pressure or concentration is maintained. When this diminishes disruption takes place.

In this way new proteins are formed by the union of protein radicles with carbohydrate radicles, and in the same manner fats are synthesised from carbohydrates.

The selective power of each tissue varies. Thus the tissue cells and the blood corpuscles are rich in potassium and phosphatic ions and poor in sodium and chlorine, whereas the converse obtains in the fluids bathing the cells. This is due to the fact that the proteins of the cells have affinities for absorbing potassium and phosphorus, but not sodium and chlorine, whilst the fluids have an opposite tendency.

This theory of the peculiar distribution of the salts is much more satisfactory than that the cell wall is a membrane with varying resisting power to the passage of the various ions. It does not destroy the argument for osmosis, but only denies the existence of a membrane and postulates the whole chemical structure of the cell as the osmotic machine. The bioplasm holds the crystalloids in loose union in the cells, preventing their escape or diffusion, and yet permitting their still further ability to attach other molecules by residual affinity.

Water (*its absorption and excretion*).—As the human body consists of close upon 70 per cent. of water, it is manifest

that in one way or another its ingestion demands our careful attention. Where too little fluid is supplied, the blood maintains a higher specific gravity and the poisonous waste products of tissue or cell change are only cast off very imperfectly. In addition to being incorporated with the tissues and forming the chief ingredient of all the fluids of the body—thus enabling them to maintain their proper degree of dilution—water plays an important part in the economy by moistening the mucous and serous membranes, and thus reducing friction to a minimum. Through the fluid media of the blood and lymph it distributes the body heat, and by evaporation it regulates the temperature.

In whatever manner, therefore, it can be introduced, its supply is of prime importance. However he may sustain the deprivation of food, man can only survive for a few days without water, and even in a few hours is seriously indisposed by its restriction. As he excretes some two and a half litres (four and a half pints) per day, it is requisite that he should partake of this quantity either in association with his food and food accessories or else in the shape of pure water. Close upon a litre (one and a half pints) are usually included in his daily diet, so that leaves more than a litre and a half (about three pints) for liquid consumption. Yet few people can be persuaded to indulge in such a large quantity, and even then it is chiefly in the shape of tea, coffee, cocoa, or even alcohol, despite the well-known solvent properties of pure water. Doubtless a large number of obscure aches and pains and imperfect tissue-functioning are due to this abstention from water.

When taken to excess, especially at meal-times, it is prone to set up symptoms of indigestion, loss of appetite, sensations of "fullness," flatulence, &c. This is because the stomach can only absorb a minute proportion of its liquid contents, by far the greater part being expelled into the duodenum prior to the expulsion of its solid contents. It is remarkable, however, that this lack of capacity for absorption is not shared by other fluids, such as alcohol, the purins of meat-extracts, the essential principles of tea and coffee, all of which are rapidly taken up by the gastric mucous membrane. Hence the rapid restorative or stimulating properties of these substances, and

the quick temporary relief which follows their use in cases suited for their administration.

The bowel in a state of health is quite capable of dealing with two litres (three or four pints) of water daily, in addition to the ordinary solid food.

The physical condition of water is not a matter of indifference to the system, as its effects vary according to its temperature. Cold water stimulates the flow of gastric juice, and hence is contra-indicated in hyperchlorhydria. It is less rapidly expelled from the stomach than hot water, a pint being ejected in three-quarters of an hour. It is also said to act more as a diuretic than hot water, more of which is retained in the alimentary canal. I should think, however, this question is largely one of idiosyncrasy.

All of the most intimate metabolic processes would be impossible without the presence of water. These are chiefly of the nature of hydrolysis or hydrolytic decomposition, sometimes effected by hydrolytic ferments, or they may consist in dehydration, or again of a mere loss of the water of crystallisation.

The quantity ingested varies according to the social position, habits, and habitation of the individual; but besides the amount consumed by drinking, we must take into account the "oxidation water" resulting from the combustion of hydrogen in the food. This will, of course, depend on the metabolic activity, but it is calculated that every hundred calories of food, whether fat, protein, or carbohydrates, yields about 10 grams of water. The potential energy of a mixed diet should be distributed as to one-sixth of the total amount from protein, one-third from fat, and one-half from carbohydrate, so that about 300 grams of oxidation water would be derived from 2,500 calories of food.

Excretion of Water.—It would be manifestly impossible to follow an individual molecule of water through all its interchanges, although it provides a wide scope for the fertile exercise of a vivid imagination. It will suffice if after its absorption, which will be more minutely described in connection with the salt-free diet, we take cognisance of the various channels by which water makes its escape from the body. As practically all the excreta with the exception of the fæces are in solution, this provides an interesting survey. About 50

per cent. of the water we swallow is eliminated by the kidneys, holding in solution urea, uric acid, ammonia, sulphates, and other waste matters from the breaking down of the proteins; 28 per cent. is excreted by the skin, from which it passes off as perspiration and sebaceous matter, containing some of the fats; 20 per cent. by the lungs in the shape of watery vapour, holding in solution waste matters from the katabolism of the carbohydrates and some of the fats; 2 per cent. by the bowels, where it tends to soften the fæces.

On a mixed diet from 60 to 120 grams of water are excreted daily in the fæces, whereas on a vegetarian diet as much as 300 grams may escape in this way.

From 1,350 to 1,500 c.c. of water are excreted each day by the kidneys, but the quantity varies inversely with the amount evaporated by the skin in perspiration. From 1.5 to 2.5 litres may be thus evaporated during moderate work and 3 litres or more with hard work. In the 15 cubic metres of air expired daily by persons at rest, about 400–500 grams of water are evaporated, so that if 930 grams of water be lost daily during repose by evaporation, 530 grams, or 60 per cent., would come from the skin, and 380 grams, or 40 per cent., from the lungs. Exercise and exposure to the sun's rays increases the evaporation. Increase of subcutaneous fat lessens the water lost at low temperatures, but increases it at high temperatures. Increase of drinking water increases the amount of urine, but leaves the evaporation from the skin and lungs unchanged.

Evaporation of 1 litre of water causes a loss of 580 calories of heat. When the loss of heat occurs too slowly, then the temperature of the body rises: one degree of elevation of the body temperature in a man of 70 kilograms is caused by the retention of 60 calories. One of the objects of training, therefore, is to effect the excretion of sweat before the temperature of the body has risen unduly.

Diuresis produced by an increased consumption of water is accompanied by an increased excretion of nitrogen in the urine, but this is only a washing out of what is stored up in the tissues and not due to abnormal disintegration of the protein. The body clings with avidity to its extractives, which is surely an indication that they are not quite so useless as has been supposed.

If no fluid be drunk at all, then only 500 c.c. of water from the food and 300 c.c. oxidation water are available for excretion. The excretion of urine may, therefore, amount to no more than 200 c.c., and the calculated perspiration—slightly different to the evaporation of water from skin and lungs—may fall from 1,000 grams to a few hundred grams, the loss being chiefly due to diminished cutaneous activity.

For further discussion of this subject, reference should be made to the chapter dealing with dietetic theories associated with water.

MOVEMENTS OF THE ALIMENTARY CANAL

The Stomach.—The classical description given by Dr. Beaumont, that there was a movement of the gastric contents from the cardia along the greater curvature to the pylorus, and then back again along the lesser curvature, is no longer tenable since the researches of Cannon on living animals. By means of the fluoroscope and the X-rays he has established the fact that the fundus acts as a reservoir, slowly pressing its contents through a ring or muscular band—the transverse band or sphincter of the pyloric antrum—between it and the pyloric portion of the stomach. The part of the fundus nearest the pylorus converts this tonic constriction into waves passing towards the pyloric portion at regular intervals of fifteen to twenty seconds. When the liquefied food reaches the pyloric side of the transverse band, it is carried forwards by the running waves and then by contraction of the muscular walls pushed backwards to the afore-mentioned ring.

The mixing takes place entirely in the pyloric portion of the stomach, the contents of which are never commingled with those in the fundus. Indeed, the mass of food in this latter part of the stomach remains in layers, which arrange themselves in accordance with the order in which the items of the meal are swallowed. For this reason, salivary digestion is able to be carried on until the secretion of the hydrochloric acid penetrates the mass sufficiently to neutralise the alkaline saliva. This ensues in the space of three-quarters of an hour, or it may be as long as two hours, and then proteolysis begins slowly to take place.

It is contended that carbohydrates should be eaten at the beginning of a meal, for by this means free hydrochloric acid will appear rapidly, because there is no protein to combine with it. Now, as free hydrochloric acid is the mechanism causing the pylorus to relax, the stomach contents will in such case be much more quickly expelled into the duodenum, leaving the subsequent protein food to be more efficaciously dealt with in the absence of starches. When the contractions in the pyloric portion of the stomach have produced a thorough mixing of the food with the secretion, and when the necessary free hydrochloric acid has developed, the pylorus relaxes and the acid contents are propelled into the duodenum. The pylorus then contracts, and the alkaline secretions of the pancreas, intestine, and liver neutralise the acid chyme ejected from the stomach. When this is completed, the pylorus again relaxes, and this procedure goes on automatically under the influence of reflex action, until the stomach is emptied and in normal cases becomes microscopically clean. By this arrangement the acid stomach and alkaline intestine are kept from injuring each other.

When this description of gastric digestion was first published, physiologists hailed it with delight, and accepted it literally, but further experimentation and reflection have presented some difficulties, so that later observers are not inclined to accept the statement without reservation. At any rate, different interpretations are put upon the appearances as seen through the fluorescent screen, and this is hardly to be wondered at when we remember the difficulties associated with all X-ray diagnosis. It is rather startling at first, in examining with this apparatus a person in the erect posture, to notice that the apparently normal stomach is situated much lower down in the abdomen than we were taught to expect to find it. It would not be surprising if we are compelled to change our views on this matter also. Amongst others, Hutchison has pointed out that whilst the presence of free HCl seems to increase the activity of the movements, these are able to take place quite efficiently when no gastric juice is secreted at all, as in cases of achylia. Then he mentions several reasons why the presence of free HCl in the stomach should not be looked upon as the mechanism for causing

relaxation of the pylorus, amongst them the fact that in cases of gastric fistula excess of acid may cause pyloric spasm, and, at all events, free HCl in these cases tends to inhibit the opening of the pylorus. These are not altogether conclusive reasons for rejecting the new view, as the conditions in disease need not necessarily be similar to those in health.

Besides, there is no doubt that the pylorus exercises a certain amount of discrimination before deciding to relax and permit the exit of its contents. The passage of fluid takes place early, in jets of a few c.c. four times a minute, and is hardly ever delayed. Hard substances and indigestible masses are not only rejected by a tightening of the pylorus, but carried back by a reflex current, and this causes a delay in the exit of softer food as well.

Carbohydrates begin to leave the stomach within fifteen minutes, and with such rapidity that they are all expelled within three hours. Fats pass out much less freely, although less than half an hour elapses before they begin to enter the duodenum, but at the end of six hours much of the meal still remains in the stomach. Proteins never leave the stomach before the end of half an hour, although in six hours they have usually all been ejected. Proteins delay the exit of carbohydrates, while fats exert a deterrent influence on the escape of both proteins and carbohydrates. Probably the order of procedure is controlled by the stage when liquefaction or digestion is effected by the gastric juices.

In fasting animals and in certain digestive disturbances, the pylorus may open to allow a reflux of digestive juices from the intestines. Excess of fatty acids, *e.g.*, when too much fat is given with the food, and excess of hydrochloric acid passing into the duodenum, causes a free secretion of bile, pancreatic fluid, and succus entericus. Neutralisation follows, the pylorus opens, and the fluids pass into the stomach.

The Intestine.—The contents of the small intestine are propelled forwards by a combination of pendular movements producing rhythmic compression and relaxation, and true peristalsis at the rate of approximately 1 inch per minute, but in addition are thoroughly mixed by a process called “segmentation,” described accurately by Cannon and more recently as seen by Hertz under the X-rays. “The shadow of a short

length of small intestine, at first uniform in thickness, becomes constricted in its cavity, the constriction increases until the single shadow is more or less divided into two. Then each half undergoes a similar division, but the two central segments of the four thus produced join together; the new central segment then divides again, the segmentation continuing in one place at the rate of ten divisions in one minute and a half."

By this means the food is thoroughly mixed with the bile, pancreatic and intestinal juices, and is brought into frequent contact with the absorbing mucous membrane—a fact of the first importance.

After a mixed meal the average time when food begins to appear in the cæcum is four and a half hours.

Judging from the sounds heard by the stethoscope, the contents of the ileum are projected into the cæcum in jets, and on a mixed diet fats reach the cæcum before proteins, proteins earlier than bread, and more than half of a quantity of milk ingested reaches the cæcum in two hours at the outside. Most of the chyme is absorbed before the cæcum is reached, only 9–10 per cent. of the proteins of a meal appearing there, and a further 2–3 per cent. being absorbed in this portion of the colon, whilst only 2 per cent. of carbohydrates and 5 per cent. of fats reach the cæcum, and of these quantities a further absorption of $\frac{1}{2}$ per cent. of the former, and 1–2 per cent. of the latter takes place. There are no movements in the large intestine until a sufficient amount of material has been accumulated in the cæcum and ascending colon to produce a certain amount of distention, and then peristalsis at a lower rate than in the small intestine gradually propels the food along to the pelvic portion of the colon. In addition to pure peristalsis, other movements take place in various parts of the colon; antiperistalsis, oscillatory movement, and a general contraction occurring in the ascending colon, while shortening of the longitudinal fibres and a downward movement take place in the ascending colon.

A little fat, sugar, and coagulable protein in different stages of digestion are included in the 350 grams of fluid material passing through the ileo-cæcal valve. This quantity is reduced to about 140 grams, which is the daily amount of the fæces,

and hence a certain amount of absorption is effected by the colon.

To Hertz must be credited the most accurate observations on the length of time required for the contents to pass along the alimentary canal. He says: "The average times taken are four and a half hours to the cæcum, six and a half hours to the hepatic flexure, nine hours to the splenic flexure, and eleven hours to the commencement of the iliac colon." Some of this material may be evacuated along with the fæces, but the greater portion remains in the pelvic colon for another twenty-four hours, whence it should be expelled at a subsequent defæcation.

The whole of the large intestine below the splenic flexure should be emptied during a normal defæcation.

Fæces and their Composition.—We are thus led by the natural sequence of events to consider the composition of the fæces, a subject, like most of those already mentioned, of great interest in connection with our interpretation of the dietetic theories soon to be discussed.

It was formerly thought that the fæces consisted of nothing but food residuum, but it has now been abundantly proved that their composition is much more complex and is derived from several distinct sources. In the first place, the secretions of the stomach, pancreas, liver and intestine contribute an important share, and in this way bile acids, small quantities of pancreatic juice, hydrobilirubin, stercobilin, lecithin, cholesterol and some decomposed bile salts may all be found in association with dead epithelial cells from the mucous membrane. In addition, we find the remains of indigestible substances taken with the food, such as cellulose, keratin, mucin, chlorophyll, gums and resins, as also food residues which have escaped absorption, and actual undigested food when too great a quantity has been ingested, *e.g.*, tendons, elastin, uncooked starch, various phosphates and salts of the alkaline earths, neutral fats, &c. Water is always present in variable proportions, depending upon the diet, but an average of 75 per cent. is usual, while bacteria of all sorts, and the products of the decomposition of food such as indol, skatol, phenol, fatty acids, hæmatin and insoluble soaps of calcium and magnesium are usually to be met with.

The composition of the fæces will vary according as cellulose is or is not present in the diet. Even during fasting, fæces are still excreted which are similar to those found on a cellulose-free diet, consisting chiefly of digestive secretions; *e.g.*, Cetti, the professional faster, voided 20 grams of fæces per day, equal to 3.47 grams of dried substance. In isolated loops of the intestine in living animals Hermann found after three weeks fæcal substance weighing from 13 to 20 grams after drying.

Unless the food contains cellulose, there is little or no food residue, and therefore no protein, soluble carbohydrate, nuclein, nor connective tissue is to be discovered. On a concentrated cellulose-free diet, 70 per cent. of the fæces consist of water and the other 30 per cent. of fatty acid soaps, lecithin, a little neutral fat, mucin and nucleoprotein, but no protein nor starch. The ash is chiefly calcium phosphate.

All animals, however, require ballast of some kind in their food to provide an indigestible residue, whereby peristalsis may be stimulated and the essential fæcal elements removed. For this reason carnivorous animals eat bones, granivorous birds sand and feathers, and the herbivorous animals enormous quantities of cellulose. Rabbits soon die on a cellulose-free diet, but when horn parings are substituted life is prolonged indefinitely. The weight of the dried fæcal residue in man on a purely animal diet is from 13 to 28 grams, on a mixed diet from 30 to 40 grams, and on a purely vegetable diet as much as 74–115 grams, equal to from 300 to 400 grams when actually voided, and containing quite large quantities of protein and carbohydrate.

By adding cellulose to the diet, therefore, there is not only some food-residue, but because of this an increase in the other constituents of the fæces. There is a greater secretion of succus entericus because of the increased peristalsis due to irritation of the cellulose and the bacterial decomposition of the carbohydrates. Strassburger has demonstrated that quite one-third of the weight of dried fæces consists of bacteria, chiefly dead, and that 128,000,000,000 are evacuated daily.

Cellulose consists of the cell walls of plants, including their fibro-vascular bundles, but is usually regarded as indigestible or insoluble starch. So far as is known, no enzyme exists in

man for its dissolution, but from 5 to 50 per cent. of it, depending upon the method of preparation of the food, is decomposed, probably by means of bacteria, carbonic acid and marsh gas being at the same time evolved. It has long been known from experiments on ruminants that from 60 to 70 per cent. of cellulose is utilised, and from 30 to 40 per cent. of the cellulose of sawdust and paper is absorbed by sheep when mixed and eaten with hay.

Varying proportions of the food-stuffs are recoverable from the fæces in accordance with their preparation and the method of their ingestion. Proteins are generally well absorbed when taken in the usual forms of flesh foods, eggs, milk, &c., there being not more than a loss of from 5-7 per cent. in a full diet of 100 grams of protein, or from .8 to 1.2 grams of nitrogen. On a coarse diet, where vegetables, fruit, and wholemeal bread are the chief nutrients, there is a loss of from 3 to 4 grams of nitrogen, equal to from 15 to 30 per cent. or more of the total protein. The loss is always less on a suitable well-balanced mixed diet than on a one-sided diet.

In the case of vegetable protein-containing foods, a large proportion of the protein remains undigested by reason of its insoluble cellulose envelope, and hence cannot be absorbed. Voit has shown that quite 42 per cent. of the nitrogen present in a vegetarian's food was evacuated in the fæces, although we know there is practically no food-residue if the food be free from cellulose. These facts rather lend colour to the view that there is little fear of auto-intoxication on a meat or mixed diet in a healthy subject where moderation is observed and an efficient evacuation of the bowels occurs daily. It is to be noted that on a vegetarian diet there is on the contrary always some surplus of unabsorbed protein; but apart from the fact that it is claimed that vegetable protein is less putrefiable than animal protein, and that most of the protein is encased in an insoluble covering of cellulose, intestinal stagnation is much less likely, and hence absorption of toxins most unusual.

Amongst the carbohydrates, sugar and dextrin are usually completely absorbed, but one or two grams of starch, equal to less than 1 per cent. of a mixed diet containing from two to four hundred grams of carbohydrates may be discovered.

It is estimated that of bread made from the finest flour 1.1 per cent. is lost, whereas 2.6 per cent. of that made from coarse flour, 7.4 per cent. of that made from wholemeal, and as much as 10.9 per cent. of that made from sour rye flour may be lost. Besides, in such cases fermentation is apt to arise, lower fatty acids are found in the colon, and these excite peristalsis. On a mixed diet it is calculated that from 1.2 per cent. of the carbohydrates is lost, and on a coarse diet the loss is as much as 5 per cent.

Where small quantities of fats are taken there is often a much greater loss, both proportionate and actual, than when large supplies are ingested. On an average, however, the loss is about 5 per cent.

In cases of chronic constipation the fæces are reduced in amount from 50 to 75 per cent., and this applies not only to the contained water, but to all the constituents, even including cellulose.

It is interesting to note, therefore, that practically none of the food-stuffs escape digestion except those entangled in the meshes of a cellulose envelope. On account of the greater peristalsis, when cellulose is present the fæces contain more fluid.

The following is a comparison of the fæces excreted in mixed and vegetarian diets respectively:—

Mixed diet	...	{	35 grams dry substance.
		}	100 grams water.
Vegetarian diet	...	{	75 grams dry substance.
		}	260 grams water.

Rubner states that the average fuel value of 1 gram of the dry organic substance of the fæces is 6.2 calories.

THEORY OF INTESTINAL AUTO-INTOXICATION

We have now followed every nutrient and food-accessory from the moment of its entry to its exit from the body, and so far as our knowledge permits, have accounted for its decomposition and the disposition of its end-products. The problem is, however, not nearly so simple as this survey would appear to set forth. We have taken notice of the fact that in addition

to the dissolving operations of the digestive ferments, a precisely analogous process is effected by bacteria. The results of these two agencies are capable of being estimated with some degree of accuracy, because their products are for the most part tangible and accessible, but the problem is still further complicated by the undoubted existence of autolysis, a digestive action in the tissues themselves, and, in certain circumstances, by the formation of by-products in the alimentary canal, due to putrefaction or other decomposition of the food substances themselves. This last series of changes is effected by the bacteria normally present in the digestive tube, and the view has been advanced, especially by Combe, that the absorption of these by-products is responsible for the condition now so well known as intestinal auto-intoxication. A brief description of the arguments for and against the existence of this condition will enable us with greater precision to estimate the respective advantages of the various dietetic theories we are about to discuss.

Although the theory owes its inception to Bouchard in 1882, glimmerings of it may be discovered in the writings of others many years prior to this date. It first took solid form in 1868, when Senator directed attention to intoxications the cause of which, he said, resided in the intestines—a more correct view than that of Bouchard, who believed that they were due to dilatation of the stomach. Since that time the literature on the subject has been immense, and every one who has read Combe's well-known treatise must reckon with this latest factor in the production of chronic disease.

As the process takes place to a certain extent in every one, it may be looked upon as normal, and only when it has an ultimate sinister effect on the health can it be pronounced malign. When this occurs, either serious mistakes in diet—generally in the way of excess—have been allowed to take place, or else there has been a marked weakening of the natural defences of the body. It is usual to aver that excessive ingestion of protein food is the cause of offence to the system, but this is held only because we are much better acquainted with the chemical decompositions arising from the albuminous molecule than with those of others. Fatty acids producing "acidosis" may accumulate in the blood

from the partial oxidation of fats ; the fermentations of carbohydrates are apt to give rise to lactic, succinic, butyric, and other acids, which may injuriously influence the blood just as much by diminishing its alkalinity. From daily observations in practice one can hardly escape the conclusion that rheumatism—at least of the muscular variety—can arise from excessive quantities of acid in the body. I have repeatedly seen arthritis produced by indulgence in a dish like stewed rhubarb or stewed plums, and whatever be the explanation, it is closely bound up with the ingestion of more acid than the system can tolerate. The function of the kidneys is to eliminate excess of acid from the alkaline blood, and if they fail in this duty, then auto-intoxication must arise, because the blood is not alkaline enough to absorb carbonic acid from the tissues. We cannot afford to lose sight of these facts, in view of some of the after-effects of the administration of soured milk.

The Putrefaction of Protein.—It is recognised, however, that the protein molecule and the intestinal juices are liable to putrefaction in the intestinal canal, with the production of fatty acids, ptomaines, and leucomaines (with their secondary products of decomposition, neurin and muscarin), and many aromatic bodies of the nature of phenol, indol, skatol, &c.

Indol, in particular, is the result of the microbic intestinal putrefaction of the proteins, the precursor of which is tryptophane. This was clearly established by Hopkins, the discoverer of tryptophane, and more recently by Underhill in an elaborate research, during which he elicited the interesting fact from a clinical point of view that gelatine does not contain the tryptophane group, and its administration causes a diminished formation of putrefactive products. Hence the indol in the colon and the indican—or, to give it its full name, indoxyl sulphate—in the urine, which is the subsequent form in which it is excreted, are reduced in amount. It is a remarkable fact that indol may even be found in the lower part of the small intestine should any stasis or obstruction arise. An observation which has frequently been made is that indol is formed during starvation, and this has been specially demonstrated during the fasting experiments of Cetti and others. Some have attributed this to the autolysis of the

tissues, but on the whole the explanation is considered to reside in the fact that hæmorrhages arise during starvation, and the blood thus exuded, in addition to the intestinal juices, undergoes microbic putrefaction.

It is averred that these toxins are absorbed by the intestinal mucous membrane, and that they are the insidious cause of the most grave and fatal chronic maladies. Catarrhal diseases of every form, cutaneous eruptions, Bright's disease, hepatic disorder, neurasthenia, hypochondria, apoplexy, arterio-sclerosis, and premature old age are directly traced to the formation and absorption of these toxins found in the intestinal canal.

It is comforting to think, however, that nature has provided the body with many defences against this terrible risk of poisoning, the most important being the hydrochloric acid of the gastric juice—although it is significant that complete removal of the stomach is unattended by increased putrefaction—and the maintenance of the effective digestive capacity of the stomach and small intestine.

The bacteria of the intestine may be divided into the aërobic saccharolytes which feed upon the fats, starches, sugar, and dextrine, and the anaërobic proteolytes which feed upon albuminous substances. The activity of the former produces acids (lactic, acetic, succinic, butyric, &c.), which inhibit the operations of the latter, so that internecine warfare is constantly taking place for the upper hand.

Despite the alkaline secretions of the small intestine, its reaction is acid, owing to the production of the organic acids in the manner just mentioned, and hence little opportunity is given for the triumph of the proteolytes. When, however, any interference with the absorptive capacity arises, or stasis takes place, then putrefaction is apt to occur. Excessive consumption of highly nitrogenous foods like meat, eggs, cheese, &c., especially if not fresh, encourages the anaërobic, whereas careful and slow mastication of abundant starchy foods, with the swallowing of air coincident with this operation, favours the aërobic saccharolytes.

The large intestine, however, is the seat of election for the production of toxins, mainly owing to the fact that it is prone to inactivity and atonicity from our too sedentary existence.

As a rule, in the small intestine the factors just detailed suffice to prevent any trouble, but the colon requires the interposition of the other no less important means of defence, the chief of which is its own mucous membrane. This exercises its protective function not only by its epithelial cells and leucocytes, but also in the outflow of mucus, which hinders the absorption of the poisons by preventing their contact with the living tissue. So long as the mucous membrane of the intestines is intact, little trouble need be anticipated from the ever-present toxins, but when inflamed, as in colitis, or ulcerated, its protective function is in abeyance.

The liver, the thyroid gland, the suprarenal capsule, and the pituitary body are, according to one theory, all possessed of a toxicolytic property which adds to the defences of the body. When these organs fail in their duty it falls to the organs of excretion, the lungs, salivary glands, skin, bowels, and kidneys, to eliminate the poisonous substances from the blood; but the kidneys bear the brunt of the work, with subsequent disadvantage to the integrity of their texture. Given, therefore, a normal individual who neither eats too much nor too often, who keeps his animal food within reasonable proportions, and limits the amount of fluid he consumes at meal-times, there is little fear of auto-intoxication; of this we have abundant evidence in everyday life.

Fascinating as this theory undoubtedly is, and supported by the authority of many capable observers, it does not lack critics of weight who have advanced many objections. Hertz doubts whether indican and ethereal sulphates can in any degree be a measure of auto-intoxication, as "different putrefactive bacteria produce different products, some of which are comparatively innocuous, whilst others are excessively poisonous." In constipation the ethereal sulphates are actually diminished, and so he concludes that there is "no chemical evidence that an abnormal amount of decomposition occurs in the intestines of constipated people." On the contrary, there is reason to believe that there is less decomposition in constipation, and this would account for the lack of headache in the presence of serious constipation. Yet he admits that the symptoms of constipation are best explained by the theory of auto-intoxication, and is inclined

to attribute this variableness to functional or organic disease elsewhere in the system. I can corroborate this statement from a case under my care in which no headache was ever experienced during the most obstinate constipation until after an attack of herpes zoster in the right frontal region, since which time the slightest degree of constipation is presaged by headache in this part.

The rapid relief of a headache which is obtained after the bowels are opened is explained by Hertz on a reflex basis, on account of irritation of the mucous membrane of the colon, and especially of the rectum, by retained fæces. Kellogg's explanation of this rapid relief is that the liver has a certain degree of toxicolytic power which is exercised with ease up to a certain point, but that even the smallest addition of toxins beyond this limit is accompanied by evidences of toxæmia; the discharge of the mass of toxins in the fæces immediately relieves the strain and reduces the toxins below its destructive capacity. It has been suggested that in prolonged cases of chronic constipation the mucous membrane of the colon has a reduced power of absorption for such toxins.

The arguments in favour of the theory may be criticised, but cannot be refuted, and in the light of the enormous amount of evidence in its favour we must admit the existence of auto-intoxication not only as a fact, but as a factor of immense importance in the incidence of disease. Its malevolent influence is more easily recognised in those exaggerated cases of constipation included under the term chronic intestinal stasis, in which kinks seriously delaying the transmission of the bowel contents occur to such an extent that ample time is afforded for unmistakable putrefaction and decided absorption of the toxins. It is in such cases that the doctrine leaves the realm of theory and assumes an importance sufficiently great to suggest the advisability of such a grave operation as total or partial removal of the colon for relief of the symptoms. Let us hope, with the *British Medical Journal*, that the "medical and surgical study of disorders of digestion may make so much progress that a rational dietetic system may altogether eliminate the causes of the disorders which to-day medicine uncertainly, and surgery in a more drastic manner, seek to alleviate or cure."

CHAPTER III

VEGETARIANISM IN THEORY AND PRACTICE

It may appear almost paradoxical to commence our study of modern theories of diet with that which is the most ancient both in theory and practice, for the fleshless system of diet has never been without representatives at any period of the world's history. When one considers, however, that most of these theories have been enunciated as an apology for vegetarianism, or, in any case, that the tendency of most dietetic theorists is to gravitate towards a fleshless system, it will be evident that a careful consideration of this subject will prepare us for a more critical appreciation of the other theories.

There is reason to believe that the early history of all great nations was distinguished by a simplicity in diet and a preference for a frugivorous system. Greek and Roman athletes affected the fleshless diet. Cæsar's armies conquered the Western world on maize and oil, and his writings bear testimony to the serious grumbling of the soldiers when mutton and beef were substituted. As nations increased in wealth, luxurious habits were developed and people abandoned themselves to voluptuous living. Laziness and excessive indulgence in animal food are usually associated under civilised conditions, and by degrees the nation deteriorated and, as a degenerate race, gave way under the constant pressure of the more heroic peoples, so that its decline and fall was assured.

History abounds with notable names of philosophers, poets, historians, &c., who found it an advantage for physical or moral reasons to abstain from flesh foods. Many of them endeavoured by voice and example to influence those around

them, but with the exception of Buddha, whose authority was unique and, aided by climatic reasons, has persisted even until to-day, most of them lifted their voices in vain, and made little impression upon the nations to whom they spoke. The power of the pen was limited, and education was exclusive. Now that both are mighty forces amongst the people, the modern diet-reformer has a better chance; and under the potent influence of men like Kellogg, Graham, and Haig, the ranks of the vegetarians grow apace.

The Professional View.—With a few notable exceptions, vegetarianism has never commended itself as a cult to the medical profession; but this is not a criterion of great value, for we know how conservative medical men have always been in the adoption of even such admitted facts as the advantages of total abstinence, the use of anæsthetics, the practice of vaccination, &c. It is interesting to note what present-day medical writers on dietetics have to say on the subject.

Davis says: "Few persons live upon a purely vegetarian diet. Those who do so, show languor and a disinclination for physical and mental work, lose vigour, and become less able to resist disease. Because a vegetable diet is an economical one, it has sometimes been forced upon bodies of labourers, but uniformly the decrease in the amount of work that they were able to perform more than counterbalanced the decreased expense of their food. In vegetables enough protein cannot be found to make it possible to substitute them for meat for the purpose of maintaining life and strength. As vegetable protein is very imperfectly digested and absorbed, a sufficient vegetable diet must be a very bulky one. It will maintain strength, and by eating vegetable food only, one may be able to lift as much, but he will not be able to work so fast as on a mixed diet, but will lack energy and alertness. It is quite evident from man's anatomical structure, physiological functions and habits of living, that a mixed diet is best adapted to his needs. At the same time it is unquestionably true that too much meat is ordinarily eaten by many individuals."

Hutchison, who is usually quoted with unction by vegetarians, says that a vegetable diet is too bulky, is less digestible in the stomach, and more inclined to undergo fermentation in the intestine, with the production of acids. Its proteins are

less easily absorbed and it is greatly deficient in protein content. It tends to diminish energy and the power of resisting disease, and whilst advocating its adoption as a therapeutic agency he adds, "It is inadvisable in any case to continue the vegetarian plan for more than three weeks at a time."

Gautier recommends meat as necessary for the hard worker because "It still remains the chief stimulator and regenerator of muscle." He points out that the albuminoid principles of a vegetarian diet are only assimilable in the proportion of 83 per cent., whereas 96 per cent. reach the blood if they originate from meat. Its great lack, in his opinion, is the nerve-excitant function contained in the alkaloids of muscular flesh, with which neither gluten nor albumin can provide us. He believes that physical energy may be maintained without flesh, but looks upon man as omnivorous by instinct, dentition, digestive secretion, and his need of activity, and therefore that he must have stimulating aliments which furnish him with the most active and the most digestible plastic matter in the smallest bulk.

He considers the advantages of vegetarianism are (1) those which result from temperance, (2) that under its influence the tendency to arthritic, acute or rheumatic diatheses, neurasthenia, &c., disappears or is weakened, (3) that the character becomes more simple and the mind enjoys more rest and perhaps more acuteness.

Its disadvantages, on the other hand, are (1) that it is not suitable to a constitution weakened by hereditary illness, age, &c., or to delicate stomachs, (2) that it requires a greater volume of food, (3) that it furnishes too much lime and is apt to provoke arterio-sclerosis, (4) that an exclusively herbaceous vegetable diet provokes intestinal catarrh and visceroptosis. He thinks that many of these disadvantages may be eliminated by degrees, as hereditary custom must be allowed for, and that whilst an absolute vegetable diet is, as a rule, unsuitable for white men, this statement does not apply to the lacto-vegetarian system. In his opinion this has the following advantages. It alkalisés the blood, accelerates oxidations, diminishes nitrogenous losses and toxins, diminishes the tendency to skin disease, arthritis, and congestion of the

internal organs, makes men peaceful, not aggressive nor violent. It is practical and rational, and should be accepted and commended by those who pursue the high ideal of the formation and education of gentle, intelligent, artistic, and nevertheless prolific, righteous, and active races.

These three are excellent samples of the opinions of recognised writers on dietetics, and most of the others advance views which are in complete accord with them. Voit asserts that it is perfectly possible to subsist on a vegetable diet, but that a mixed diet is preferable. Rutgers demonstrated that animal protein could be entirely replaced by vegetable protein without any appreciable change in the nitrogen balance. Craemer declares that sufficient nourishment for the body will be found in a diet of vegetables, eggs and milk, but if the eggs and milk be omitted, the body will find it much more difficult and less economical to obtain its requisite quantity of protein.

Vegetarian Arguments.—These are examples of the opinions of scientific medical dietists of different nationalities, representative of the view held by the great bulk of the medical profession on the vegetarian question. It is only in recent times, however, that such a favourable attitude has been adopted, and despite these statements a large section of scientific opinion is still uncompromisingly hostile, probably because of an obstinate disinclination to reconsider the matter in the light of modern knowledge. It must be admitted that in its early days no effort was made by its adherents to make the diet attractive, and the crude attempts of untutored cooks created aversion and militated against an increase of its supporters; but the application of scientific principles has changed all this, and much of the reproach of the fleshless system has been taken away by Dr. Kellogg, whose glory it is that at Battle Creek Sanitarium he has removed the method from the realm of the haphazard and raised it to the dignity of an exact science.

Vegetarian enthusiasts, both in the medical profession, and amongst irresponsible supporters outside of it, in their efforts to bolster up their practice by scientific evidence, have repeatedly shifted their ground. They originally relied upon the humanitarian argument, and doubtless in most instances this gives the clue to the origin of their practice and theory. The

discovery of the hypothetical baneful effects of uric acid on the body was at first a veritable godsend to them, and Dr. Haig was hailed as the saviour of the situation, but when he announced that the vegetables most relied upon contained apparently more purins than flesh foods, his theory was scouted as not being able to hold water, and his practice, whilst being condemned, was gradually absorbed.

More recently Professor Chittenden's low-protein theory, which, whilst advocating the value of great moderation in protein foods of all kinds, by no means rejects those containing flesh, has been greeted with acclamations by every follower of Pythagoras as a perfect explanation of his practice.

All three theories are used to support the vegetable propagandism, the favourable points of each being extracted in support, and the detracting points being calmly ignored or quietly pushed on one side. It is instructive to note how the vegetarians rely upon the statement that flesh foods are full of uric acid, which is an objection to their use, and yet continue to swallow tea, coffee, peas, beans, and lentils.

At the outset one must realise that there are two main divisions in the vegetarian camp. First, those who subsist on fruits, nuts, cereals, and who, for reasons which will presently become apparent, are now in a strong minority; secondly, those who countenance the use of milk and eggs.

Major McCay's Investigations.—The most recent study of the subject and the most vivid description alike of the dangers and inherent possibilities of pure vegetarianism is that presented by Major McCay in his contrast between the physical condition of the natives of the plains of Lower Bengal and the hill tribes of the same department of India. It is of exceptional value as being the outcome of the most accurate experimentation and the most careful observation, confirmed by residence amongst the people themselves. He himself had no interest either in the condemnation of vegetarianism or in the exploitation of a mixed diet. His sole objective was the recommendation of a system of feeding calculated to improve the nutrition of the prison population; but as a result of his inquiry he was unable to resist the conclusion that pure vegetarianism as practised by the Bengalis and Beharis was totally unsuited to their nutritive requirements, detrimental to their

health, annihilated every spark of ambitious desire, and degraded huge masses of the people almost to the level of the brutes.

The important factor militating against the health of these two races of people was the bulkiness of their diet, which was potent enough to make a complete alteration in the coefficient of absorption of all the four principles. He found, indeed, that the absorbability of each of the food-stuffs varied with the degree of bulkiness, and that this was dependent upon the extent of the distension of the stomach and consequent delay of the expulsion of its contents. This, coupled with increased peristalsis of the intestines, produced evacuation of their contents before the full proportion of nutriment had been extracted.

On a diet of cereals, pulses, fruits, and vegetables only 85 per cent. of the contained protein is capable of absorption, even when the organs of digestion are in a healthy state, free from the oppression incident to an excess of indigestible material; and so long as these conditions exist the absorption is good, whether in confirmed vegetarians or in those who are recent converts to the system. Up to a certain point, depending upon individual characteristics, addition may be made to the quantity of food without interfering with the efficiency of absorption, but sooner or later a definite point is reached where the actual bulk prevents effective absorption, and further additions to the quantity intensify the difficulty till, as in the case of the Bengalese, not more than 55 per cent. of the protein is absorbed.

Diminution of absorbability may be compensated for by increase of food up to a certain point, beyond which there is a notable reduction in the quantity metabolised. There is, therefore, for each food an *optimum amount*, which is the most economical quantity capable of being dealt with by the individual.

As the bulkiness is due almost entirely to carbohydrate foods of a low protein value, there emerges another factor of importance which complicates the situation. The presence of excessive quantities of carbohydrates induces intestinal fermentation, with the production of various acids, such as carbonic acid, lactic and acetic acids. These not only reduce the potential

energy of the food, but set up irritation in the bowel and inflammation of the mucous membrane. The value of the ingested food is thus seriously reduced, and so, in spite of the immense amount of carbohydrate material consumed, there is a complete absence of body fat and an attenuation of the physical frame suggestive of utilisation of the bodily tissues to supply the necessary energy. Such a parlous situation should give pause to one obsessed by the desire to become a pure vegetarian, and such authoritative testimony should finally dispose of any arguments in favour of the utility of a dietetic system little removed from herbivorism.

Most of the disastrous breakdowns reported amongst the young and enthusiastic converts to vegetarianism in this country are to be found amongst the ranks of those who from ignorance or bigotry have persisted in using a diet so bulky that the stomach and intestinal tract could not deal with it effectively, and who were, therefore, insufficiently nourished. It is from this point of view that the use of a pure vegetarian dietary is so reprehensible and risky, and Major McCay freely acknowledges that by a reduction in the bulk and the addition of more concentrated foods with a larger proportion of protein, such as wheat, a fairly healthy existence is perfectly possible. It should, however, be recognised once and for all that such a diet is seldom capable, especially amongst those who have been accustomed to highly nitrogenous foods, of producing a powerful and vigorous race of people, and one might assert with a fair degree of assurance that only where vegetarian foods are specially prepared is it possible for any one on such a system to attain to his fullest point of physiological activity. This is the diet which has been the subject of so many severe strictures and been almost unanimously condemned by medical scientists.

Although the vast majority of those who live on such a system are destined to exist on a much lower plane of physiological activity than the mixed feeder, from actual observation I am not disinclined to believe that where the food is carefully selected and prepared the fruitarian—as he is designated in this country—may attain to a degree of health and vigour quite up to the average. But what is exceptional in such circumstances is quite a common occurrence for those who do

not object to the addition of animal protein in eggs and milk, a system which is distinguished by the cumbrous appellation ovo-lacto-vegetarian—shortened for convenience to lacto-vegetarian—and throughout this discussion my remarks will have special reference to it. It is important to recognise its distinctive features, as the arguments in favour of and the unfavourable criticism levelled at vegetarianism originally applied to fruitarianism. There are still many strict vegetarians who deplore the admission into the diet of anything but what they term the fruits of the earth, and are ready to maintain its suitability and defend its tenets against all comers, but we have already exposed its weak points and need not return to them. All the statements about to be made concerning lacto-vegetarianism will apply with all the greater force to the more restricted system, although it must be admitted that the flesh-abstainer has enormously strengthened his position by the addition of animal proteins.

The “Humanitarian” View.—But by permitting the inclusion of eggs and milk lacto-vegetarians have deprived themselves of one of the most powerful reasons for disseminating their doctrine—namely, the humanitarian one. Apart from the personal argument, this has always appeared to me to be the strongest motive for the adoption of a fleshless diet. I have great sympathy with the man who, on sentimental, religious, or other grounds, declares that he cannot have anything to do with the death of any animal for his personal comfort; but when I find that he not only uses their skins in the shape of shoes and gloves, but allows the use of their products in the shape of eggs and milk, I realise that whilst claiming its support he has completely cut the ground from under his feet and therefore ought to have abandoned his plea. It almost amounts to equivocation to claim that a large share of the eggs eaten are sterile and hence must necessarily decay, for he must recognise that to obtain eggs and milk at a rate to allow the vendors a profit some animals must be killed. He ought to know that many fowls are fed upon fish offal and much cruelty is practised to compel miserable ailing cows to quadruple their supply of milk. It is only necessary to coop up a poor cow in a close atmosphere and feed it on the refuse from distilleries, sugar refineries, and oil presses to compel it

to produce a large quantity of thin and unwholesome lacteal fluid.

Those, too, who, still calling themselves flesh-abstainers, permit themselves fish on the plea that they object to the breeding of animals for human food, cannot surely be aware that nearly all trout, most salmon and oysters, and many other kinds of fish are regularly and constantly increased by the practice of pisciculture. As far as one can judge, nothing but good can accrue to the economy of Nature from the production for human food of eggs, milk, and fish, because it tends to the improvement of the species; but much less can be said of the questionable methods of forcing vegetables, fruits, and cereals of all sorts by doubtful kinds of rapid artificial culture.

The humanitarian argument should cover more than the death of the animal for food, and those who depend upon it are, I believe, consistent enough to object to the death of animals in sport. They are to be commended for this, and, compared with the anti-vivisectors who eat the flesh of animals, they are on a much higher plane of logic. But it is reasonable to suppose that reference to this very question of hunting gives us a clue to the origin of our flesh-eating habits, for it is sometimes difficult for one to reconcile the love of humanity with the innate desire to kill which is present in every man, especially in temperate climes. It is explicable, however, when we reflect that for many hundreds of years man was compelled to live on the products of the chase or starve. In the early history of most temperate countries the land was covered with virgin forests and possessed an inhospitable soil, so that no fruits of any acceptable kinds, few nuts, and certainly no cereals, could possibly be met with. We know that these woods were swarming with animal life, and one can easily see that carnivorism was not a choice but a necessity. It is hardly an answer to this argument to say that man had no need to leave his tropical home, because, so far as we can judge from a comparison of the peoples of the world, his transmigration was an evolutionary necessity. One need only contrast the inhabitants of the torrid zone with those of temperate climes to see that where food is or was easily obtained indolence is the characteristic of the inhabitants, and where it is or was difficult to obtain energy rapidly developed. Besides, there are regions

of the earth's surface where no nuts, fruits, or cereals can possibly be grown, as, for example, the Arctic Circle.

It has been urged in opposition to this statement that in the journal kept by the Pilgrim Fathers it is recorded that the aboriginal diet was chiefly corn, beans, and other vegetables, and that in the early summer, when these were exhausted and the flesh of deer, wild turkeys, fresh fish, clams and oysters were substituted, illness quickly broke out and was only quelled on the appearance of the new crops of corn and beans. Apparently the Indians discovered the evils attendant upon too great restriction of the diet and the advantages of a mixed diet, for all through the Central States of North America there still exist to day thousands of so-called garden spots—large clearings made by the Indians and cultivated by them. From these facts it is fairly clear that prior to the period mentioned there must have existed a precibicultural stage, when the conditions obtained which I have depicted.

But critical examination of this argument will reveal that it is by no means so powerful as at first glance it appears, for animals are killed much more expeditiously than would be their lot if they were left to die in a natural manner, and, so far as we know, they are unable to anticipate the approach of death. Both in this country and in America I have made a personal investigation into the statement that slaughtering animals tends to brutalise men and tends to convert them into the most inhuman of monsters. Except in the latter country, where slaughterers are not permitted to serve on juries, I have been unable to discover one single fact in support of such an inconsiderate statement. In England at least, they compare favourably with other sections of the community as regards the frequency of homicide and suicide amongst their members, and I am informed by those who come into contact with them daily that their natural affections are rather increased than diminished by their very necessary though perhaps unfortunate occupation. It is comparatively simple to trace the inception of this cruel slander. It is quite on all fours with the analogous condemnation of the vivisectioner and surgeon as butchers—a statement which is far removed from the truth, and in the eyes of at least one scientist—such as Dr. Kellogg—needs no refutation. His

warmhearted admiration for members of the former class is well known, and he himself is a brilliant example of the magnanimous and self-sacrificing surgeon who, but for the public association of his name with flesh-abstinence and his enthusiastic advocacy of its tenets, would be known as one of the most daring, painstaking, and successful surgeons in America.

I frankly admit the cogency of the plea that few persons would continue the use of flesh if they were compelled to kill the animals which they ate, but there are many other disagreeable functions in everyday life which would be deliberately omitted were their vicarious performance not willingly undertaken by more suitable people. However much we may deplore the existence of 100,000 slaughterers in this country alone, the lacto-vegetarian cannot be exonerated from his share of any odium attached to their calling, besides which, the average man or woman has very little compunction in quickly dispatching fish, game, or poultry for food.

It is a remarkable commentary on the humanitarian argument that, should the vegetarian propagandism succeed as the zealots desire, it will more than decimate the animal population of the globe; it will end in extinguishing it, because more and more land will be required for the cultivation of fruits, nuts, and cereals, and in time there will be no available territory for the feeding of cattle. From the humanitarian point of view this would manifestly occasion much sorrow, but it would from the point of view of economics be a cause for great gratification, because it is calculated that a given tract of land will support more than one hundred times as many people if the food be taken at first hand from it than if taken second-hand through the animal body. Even should this estimate err on the side of generosity, obviously the gain from every point of view would be tremendous if we could only be assured that the nutritive requirements of the body could be equally well served by a fleshless regime as by a mixed diet.

Vegetable versus Animal Protein.—For the settlement of this problem the evidence at our disposal is fairly extensive. If the flesh-abstainer would only be satisfied to go on utilising the unquestionable advantages of the animal proteins in milk and eggs, there is little doubt that his diet would be quite as

satisfactory as that of the mixed feeder. But although he supports his fleshless propagandism by appealing to the health and vigour capable of being maintained on the lacto-vegetarian system, he never ceases to insist that eggs and milk are not a wholesome source of protein, but that vegetable proteins are much more wholesome and safer. Now this is a question upon which there is a decided difference of opinion; for assuming that the attractiveness, and hence, according to Pavlov, the digestibility of the lacto-vegetarian system be equal to that of a mixed diet, it is quite certain that the absorbability of vegetable protein is much inferior to that of animal protein. We have already in Chapter II. quoted Voit's statement that quite 42 per cent. of the nitrogen present in a vegetarian's food is evacuated in the fæces, chiefly because vegetable protein is encased in an insoluble cellulose envelope, and we have also seen that on a mixed diet only 1.2 per cent. of the carbohydrates is lost, whereas on a coarse diet the loss is as much as 5 per cent. The dry substance in the fæces of a vegetarian is more than double that of one living on a mixed diet, the difference being accounted for chiefly by cellulose containing protein, so that in the former case it is evident that the body loses energy in two ways, first by actual loss of food, and second by excretory effort.

We have seen that proteins are broken down in the intestine into their final cleavage products, the amino-acids, which in all probability pass directly into the blood in this form, as the amount of non-protein nitrogen in the circulating fluid is increased during absorption. We have already seen that there exist a multiplicity of proteins with varied and complex compositions, and as without doubt some of them have specific functions of an important, not to say absolutely essential character, it is certainly unwise to exclude from the diet any protein-containing substances, especially those whose value has been proved in nutrition. The study of the vegetable proteins is still in its infancy, but it is already known that they possess characteristics clearly differentiating them from animal proteins, which unquestionably correspond more closely to the proteins in our own tissues. Gowland Hopkins found that mice can live longer on zein—a protein obtained from maize, containing leucin, tyrosin,

and abundant glutaminic (glutamic) acid, but destitute of lysine and tryptophane—with the addition of tryptophane than on zein alone. But neither zein alone nor with the addition of tryptophane could enable the animals to maintain their growth. The tryptophane is not therefore likely to be an actual building stone of the body, but it is suggested by Hopkins is a normal precursor of some specific “hormone” or other substance essential to the processes of the body; yet without it nitrogen equilibrium cannot be maintained.

Gelatine, again, which lacks tyrosin, tryptophane and cystine, cannot repair tissue waste, but can replace protein in so far as the latter functions as a source of energy, sharing with it in this capacity some inexplicable advantage over fats and carbohydrates. It is evident therefore that proteins may function in other still unknown ways than those with which we are familiar, and as it is yet impossible to say at present just what function they subserve in the human economy, it may be risky to deprive the body of any of them, as we may thus be denying it some important source of nutrition.

The growth and maintenance of the body may thus be compared to the building of a house, the whole of the details of which are derived from one form of structural material, viz., amino-acids. In the building of a house many kinds of structural materials—wood, bricks, glass and slates, &c.—are employed, and hence the two conditions are not quite analogous. It is futile, therefore, to compare vegetable protein to new bricks from a kiln, and animal protein to brick which has been built into complicated structures, so that when the edifice is disrupted, quantities of rubbish which the body cannot utilise are found mingled with the brick. There is, indeed, some justification for the belief that some of the waste matters introduced with flesh food, so far from being detrimental to, actually subserve, the best interests of the body. It is therefore injudicious for the flesh-abstainer to maintain his uncompromising attitude of hostility towards the moderate flesh-eater, especially when in his capacity of lacto-vegetarians he himself utilises some forms of animal proteins and so shares with the meat-eater the responsibility for killing animals.

We shall shortly deal with some of the more specific objections to a flesh diet; but at this juncture one may fairly argue

that given a personal liking for eggs, milk, and milk products, and the opportunity to obtain them in the best possible circumstances, the crux of the whole problem rests with the capacity of the individual to cope with the digestion of lacto-vegetarian foods. Granted such a capacity—and it may be at once conceded that it exists permanently in some—there appears to be no reason why a man should not be as healthy on such a system as on a mixed diet. The problem is one which can easily be, and has been, put to the test, and there is little doubt that many people, both in this country and America, exist in a high degree of physical and mental efficiency on such a diet. If we are to trust to the testimony of many of these individuals that their health and comfort have been immensely benefited by their change, it can hardly longer be contended that the highest degree of physical and mental health cannot be obtained on a lacto vegetarian diet, and that it is often indeed much more suitable than a mixed diet for a large proportion of town-dwellers.

The Irving Fisher Experiments.—A considerable amount of evidence has recently been advanced to prove that flesh-abstainers, whilst no stronger than those living on a mixed diet, are on the other hand capable of a much greater degree of endurance. This has been frequently demonstrated by many long-distance walks, but more recently by a careful set of experiments instituted by Professor Irving Fisher at Yale. The subjects of the experiment fell naturally into three groups—(1) Athletes accustomed to a high-protein and full-flesh dietary; (2) athletes accustomed to a low-protein and non-flesh dietary; (3) sedentary persons accustomed to a low-protein and non-flesh dietary. The test employed consisted of (1) holding the arms horizontally as long as possible; (2) deep knee-bending; (3) leg-raising with the subject lying on his back. Although the third item appeared to show the superiority of the flesh-eaters, the result of the other two was a distinct triumph for the flesh-abstainers. In particular, comparing fifteen of the latter with fifteen flesh-eating athletes, the average length of time the arms were held extended horizontally by the flesh-abstainers was nine times that of the flesh-eaters, or 90 minutes compared with 10 minutes.

Irving Fisher draws the following conclusions: (1) Large flesh-eaters, even when trained, show far less endurance than flesh-abstainers, even when the latter are leading a sedentary life. (2) In view of (a) the great extent of the superiority shown; (b) the heavy handicap imposed upon the abstainers; (c) the absence of other known factors to account for their superiority, it is improbable that this superiority can be explained away by adventitious circumstances. (3) It is possible that the superiority of the abstainers was due to the absence of flesh-foods or to a smaller quantity of protein or to both, as well as to the abstention from tea, coffee, and condiments.

I am personally acquainted with some of the flesh-abstainers who were subjects of the experiment, and their appearance would not warrant one in anticipating any such marvellous results, and it is fair to add that physiologists in America think that because Professor Irving Fisher is not a medical man or a trained physiologist, he is hardly competent to carry out in a proper physiological way experiments in endurance such as he reported. But I am not at all inclined to doubt the accuracy of these results, and I believe, were the experiments repeated, the results would not differ in any important degree from those just detailed.

In a paper published since the date of this experiment Professor Fisher gives some details of some tests applied at Brussels by Mlle. Dr. J. Ioteyko and Mlle. Kipiani on forty-three vegetarians, the results being quite on a par with those already quoted. "So far as strength is concerned," he says, "very little difference could be discovered between vegetarians and 'carnivores.' In endurance, on the other hand, a very remarkable difference was found, the vegetarians surpassing the carnivores from 50 to 200 per cent., according to the method of measurement." It was also found that the vegetarians recovered from fatigue more quickly than meat-eaters, again corroborating the Yale experiment. As Mosso's ergograph was used, an interesting mathematical study of the fatigue curve was made, in which the equation

$$\eta = H - at + bt^2 - ct$$

was employed.

η = height of contraction.

t = time.

H = height of initial or maximum contraction.

a = the measure of the toxicity of albuminoids on muscles.

b = the excitability of the central nervous system.

c = the utilisation of carbohydrates.

It was found after laborious computation that the average of the co-efficient a for carnivores was .00305 and for vegetarians .00015. The average co-efficient b for the carnivores was .086 and for the vegetarians .023. The average co-efficient c for the carnivores was 1.94 and for the vegetarians 1.46. The average of the constant H was 38.7 for carnivores and for vegetarians 31.7.

It appears therefore to be not now a question of simply admitting that flesh-abstinence is consistent with health, but the question is whether it may not really be conducive to superior health. This, of course, is maintained by the vegetarians, and they attribute their improvement in health to many factors, such as the low protein content of their diet and its freedom from so-called toxicity, with neither of which statements I am prepared to quarrel, although I believe two other factors are of much greater import, viz., its great simplicity and its association with more hygienic surroundings.

Arguments in Favour of Vegetarianism.—As a prelude, however, to an examination of this statement let us first carefully consider *seriatim* the reasons advanced for the superiority of vegetarianism. Many of these reasons are quite fantastical and could with equal cogency be urged in favour of a mixed diet. Vegetarians arrogate to themselves the statement that their food is pure and natural, tacitly assuming, if not openly declaring, that flesh-foods are always impure and unnatural. But one of their own number has recently launched forth into invective on this question, asserting that "there are no natural foods available for consumption in such measure as to be the basis of any sane dietary suited to the needs of civilised man, and it is to be hoped therefore that a more correct phraseology will soon be adopted in the classification of those foods to which this expression has hitherto been held to refer."

As many as thirty-nine reasons have been advanced in favour of vegetarianism, *i.e.*, translating the term in its widest significance of adopting the practice of flesh-abstinence. Quite thirty of them could with equal assurance be employed in support of a mixed diet or of any diet of which simplicity was the characteristic feature. We shall now in some detail make a careful inquiry into those which are actually conformable to reason.

(1) Animals are liable to disease which even the most rigid inspection may fail to discover, and as this inspection is of the most perfunctory character, mixed feeders are liable to consume diseased flesh, and in this way have disease communicated to them. Whatever may be said about America, and much of what was written was melodramatic and sensational in the extreme, it is unfortunately quite fair to say that the inspection to which all carcasses intended for human consumption are submitted in this country is not rigid, real, and efficient. Foreign meat and home-killed meat, so far as it refers to the large cities, are under perfect supervision, but it is quite well known that animals may be killed in villages and many small towns without any official inspection. When it is known that the flesh thus distributed contributes quite 25 per cent. of the total quantity condemned, it reveals a weak spot in our public health methods. But I am pretty certain that the production of disease amongst those who consume the flesh of diseased animals is by no means inevitable. No one would urge it as advisable, but a sufficient number of cases are on record to demonstrate the fact that not only eating the flesh of animals which have died from disease, but actually eating diseased flesh, is not necessarily risky to health. I know that "braxy" was considered a delicacy in Scotland, and I never knew of cases of illness actual or remote to arise therefrom; and I am informed that in Bengal animals dying from epidemic disease are regularly eaten without apparently any illness originating. Two diseases are specially singled out as being eminently conveyed by diseased flesh, but the selection is particularly unfortunate, as there is not a single vestige of evidence that either tubercle or cancer is more prevalent amongst mixed feeders than amongst vegetarians. There is no proof, indeed, that tubercle

can be conveyed by eating the flesh of tuberculous animals, and it is asserted that "knackers," a class of people very liable to the consumption of tuberculous meat, suffer less from tuberculosis than the general population.

On the other hand it is absolutely certain that tubercle can be conveyed by drinking milk, and as this nutriment is now included amongst the items allowed to fleshless feeders, the argument is so much the more unconvincing. An interesting statement in this connection is that made by a member of the State Board of Agriculture of the State of Colorado, U.S.A., to the effect that 40 per cent. of the hogs killed in certain parts of that State are found to be infected with tuberculosis, which is conveyed to them by skimmed milk. This milk is their chief food, and is left over after creaming by the centrifugal process. He also stated that in Wisconsin the milk routes throughout the State can be traced by the tuberculosis in hogs.

The statement that cancer is much more prevalent amongst meat-eaters than amongst vegetarians is equally fallacious, for "cancer occurs in all the vertebrates, except the reptiles (almost exclusively meat-eaters), and is found in mammals tame and wild, in amphibia, in fresh-water fish, and in sea-water fish in a state of nature. The reports of the Imperial Cancer Research Fund state that the following figures represent the classification of the natives of India who die from the disease as regards their dietetic habits: 146 vegetarians, 137 flesh-eaters, 222 on a mixed diet."

But the argument could be easily turned against the vegetarians with the assertion that more diseases are probably disseminated by the use of vegetable food than by animal food. The huge epidemics of ergotism and lathyrism from the use of rye and millet respectively, the prevalence of beri-beri from the use of uncured rice, the probable dependence of pellagra on diseased maize, all testify to this fact, although it would be quite fair for the vegetarian to retort that these diseases cannot be attributed to any condition which is essentially or inseparably connected with cereals or vegetable food-stuffs, whereas the evil consequences which they ascribe to flesh-eating are effects that cannot be separated from the practice of using flesh as a staple article of food. As, however,

there is no general agreement on, if indeed any evidence of, their statements that excessive protein, the introduction of uric acid and other waste materials in the body, the putrefaction of undigested remnants of animal protein in the colon, are the causes of disease, unless amongst those who can only be described as gross feeders, the retort is hardly appropriate, and it is always well to realise that most pathogenic organisms belong to the vegetable kingdom.

Nor is it certain that flesh-abstainers are any less liable to disease than meat-eaters, even although they start with the enormous advantage that as a body they pay particular attention to the observance of the general laws of health. This is a problem not easily solved; but in my own experience I can vouch for the fact that they are no less liable to "colds" in the head—despite many assertions to the contrary—than meat-eaters. I do not, however, attach much importance to this fact, as I believe open-air life, moderation in diet, and careful intra-nasal hygiene are more essential factors in escaping nasal catarrh than the question of the kind of protein indulged in. Then it may be surprising for me to asseverate that the most inveterate cases of constipation I have ever known have been amongst vegetarians. This, indeed, is such a great difficulty with those who live on the wholly artificial fleshless foods, that special precautions in the way of eating slabs of compressed agar-agar at each meal require to be observed in order to obviate it in many cases. The most severe case of choleraic diarrhœa I have ever treated was in a vegetarian of many years' standing, and I have seen severe and persistent sciatica, pneumonia, and most of the ordinary everyday ailments in the persons of bigoted vegetarians.

I am bound to admit that recourse to a fleshless diet is of great value in many diseases—as, *e.g.*, nocturnal incontinence of urine or an irritable bladder, because of the diminished acidity of the urine; but it is notable that since the Japanese have begun to eat more animal food, beri-beri is becoming daily less rampant in their midst. It may be asserted, without much fear of contradiction, that cooking practically sterilises animal food and takes away all possible chance of the conveyance of disease thereby. I do not mean that all the microbes

in a joint of meat are exterminated in the process of cooking, for I am well aware that the interior of a joint cannot be raised beyond 180°F. ; but there is no doubt that alterations take place during cooking which remove any risks of disease arising from its ingestion, and likewise create in it a degree of sapidity which is a valuable peptogenic quality. The characteristics of diseased meat are so well known that it is almost impossible for it to get near the dinner-table.

Waste Products in Food.—(2) Animals are slaughtered in such a way as to make their flesh rich in waste matter and dangerous as food. It is in this way (so the argument runs) that gout, rheumatism, and apoplexy are apt to arise. In his recent interesting Antarctic work Shackleton describes the frightful colic his party endured after eating ponies killed in a state of absolute exhaustion. It is quite certain that if animals are overdriven to the slaughter-house and killed immediately, their flesh is not likely to be so wholesome as if they had been kept apart and quiet for, say, twenty-four hours; but the latter practice prevails in all abattoirs under public supervision. I am quite certain that I have seen as great proportion of vegetarians suffering from rheumatism in the less acute forms as of meat-eaters, and Dr. McKenzie, of Burnley, in the *British Medical Journal*, February 10, 1906, says that the worst case of arterio-sclerosis (with a blood pressure of 210 mm. Hg) he ever saw was in a vegetarian and teetotaller.

(3) Animal flesh as sold in butchers' shops is always in a state of decay and putrefaction. Now, it is perfectly futile to deny that this assertion is absolutely in accordance with truth, because absence of life is the signal for such changes to begin; but the statement in its bald form makes too forcible an appeal to the imagination. It is an unquestionable fact that, when subjected to careful examination, flesh-food of all kinds, whether from healthy or diseased animals, reveals the presence of a large number of micro-organisms, varying in character and number with the state of the atmosphere and the time which has elapsed since the death of the animal. Dr. A. W. Nelson, of Battle Creek, reports that raw beef purchased in the open market contains 80,000 to 110,000 aërobes per moist gram, and from 14,000 to 90,000 anaërobes per

gram ; while, after cooking, the inside was found to contain from 3,000 to 150,000 aërobes and 2,000 to 160,000 anaërobes per moist gram. Sirloin steaks, as served in the dining-tables of prominent city hotels, contained 280,400,000 aërobes and 378,000,000 anaërobes per moist gram. Raw codfish (soaked to remove the salt) contained one-eighth as many, and sausages, pork, &c., quite twice as many.

It is suggested by the flesh-abstainers that intestinal auto-intoxication is encouraged by the ingestion of these putrefactive bacteria, and that the repeated use of foods containing them aggravates some of the worst features of this condition. They even stigmatise the condition as a disease, one of the earliest concomitants of which is hyperchlorhydria, and that this is evidently an exaggeration of one of the natural defences against such micro-organisms. So long as this excess of free hydrochloric acid persists they admit that the putrefactive bacteria contained in flesh may easily be destroyed by it ; but the tendency is for the free hydrochloric acid to disappear from the gastric secretion, so that its germicidal action is lost, and the billions of putrefactive bacteria swallowed at a single meal pass on into the intestine to exert their maleficent action there. They do not take into consideration the fact that of the 128 billions of bacteria which escape with the fæces daily, and constitute one-third of their bulk, not more than 3 per cent. are alive ; and A. Klein even denies that more than 1.1 per cent. of the total number passed are alive and still capable of propagation by culture. This is pretty significant testimony to the damage they have sustained by their residence in the alimentary canal.

But of the large number which still remain alive, in all probability the majority of them will prove to belong to the beneficent class of bacteria, for even Combe, the great apostle of the doctrine of intestinal auto-intoxication, admits that a well-balanced mixed diet, including milk and farinaceous foods, not only "diminishes the putrefactive phenomena in the intestine, but diminishes considerably the toxic effects" of meat. It is hardly to be expected that the putrefactive bacteria should predominate if a sufficient quantity of lacto-farinaceous material be consumed, because on a properly balanced mixed diet there should never be more than 5

grams of protein in the colon to provide sustenance for them. With an efficient quantity of carbohydrates, &c., it should be by no means difficult for the saccharolytic bacteria to keep the proteolytic bacteria in abeyance, if this be necessary. For it has always appeared to me a fact of profound import that on a diet of meat alone, such as Salisbury advocated, undoubted advantages should usually, even temporarily, accrue to the body, and especially that it should be recommended in cases of intestinal toxæmia. Still, on such a diet there is usually a craving for starchy foods, an indication of an instinctive protest on the part of the body against the ill-balanced diet.

In any case, experience demonstrates that no such evil results arise on a mixed diet containing flesh as are adumbrated by the flesh-abstainers, and that the average man is fairly capable of dealing with the poison contained in a flesh diet. Besides, Metchnikoff has issued warnings that on even apparently fresh fruit and vegetables numberless microbes exist, which should be removed by washing or destroyed by cooking before eating. It is, of course, perfectly clear that the bacteria developed in vegetables or fruit are not proteolytic but acid-forming bacteria, living upon carbohydrates, and that the undoubted diseases which arise from the consumption of such substances in summer and autumn bear immediate evidence of their origin.

(4) Flesh is stated to be a stimulating food, and may give rise to a craving for other stimulants. This is an admitted fact; but it is a question whether all the stimulating effect be due to the waste matters and not to the excess of protein likely to be consumed in eating flesh immoderately. In any case, excess of protein, even of vegetable origin, is apt to act as a stimulant. But all nations, whatever their diet, have their own form of stimulant. I am not sure whether in this country the cause of over-indulgence in alcohol, at least amongst the female sex, should not be laid at the door of excessive drinking of tea and coffee, which are of vegetable origin, and are undoubtedly much more stimulating than flesh.

(5) We are also told that the stimulants in animal food are certain secretions which have formed in the animal prior to death. It is quite certain that if the animal be overdriven and

overfed, waste matters will be found in an increased degree in its flesh, which, had it lived long enough, would have been excreted by the kidneys. We are all familiar with the statement made by Atfield, which, I believe, originally emanated from Flint, that, denied the use of his nasal organ, he would be quite unable to differentiate by any chemical process between home-made beef-tea and urine. But, as I have already said, cooking alters the character of these waste matters, and, if necessary, they could be largely separated during this process. In any case, many valuable vegetable foods contain poisonous secretions—*e.g.*, the husks of nuts, the poison in cassava roots, the acrolein in beans, and we might even mention, as we are considering lacto-vegetarianism, the tyrotoxicon of cheese.

(6) All animals living on vegetarian diet are strong and peaceful, and it is therefore suggested that man need only live in the same manner to have a similar temperament. But surely the case here is again overstated, for few of us would like to be abandoned to the tender mercies of the herbivorous bison, buffalo, or even the rhinoceros. The charge of an infuriated elephant or a savage horse is by no means to be despised, and, as I have before remarked, I consider that excess of protein in the diet is as likely to be responsible for such outbreaks as the character of the protein. The assumption that men living on a fleshless diet would be peaceable and on a mixed diet ferocious is, of course, entirely gratuitous. We cannot readily forget the ferocity of the flesh-abstaining mutineers in 1856, and we are apt to compare these fiends with the beef-fed and rum-drinking British sailor, whose characteristic traits are simplicity and child-like playfulness. The men in our Navy are to-day better fed than ever, and without doubt are infinitely better physically than at any stage in their history, and their generous natures and gentle dispositions are a great contrast to the crafty, deceitful, cunning, vindictive cruelty of many Eastern vegetarian peoples. But this is largely a question of the influence of civilisation, just as with animals ferocity is extinguished by taming.

In this connection it was pathetic, during the Russo-Japanese War, to notice the haste with which vegetarians pointed to the undoubtedly splendid fighting qualities of the

Japanese as evidence of the value of a fleshless diet, without seeing the incongruity of their argument. Perhaps less haste would have been displayed had they stopped to consider that amongst the Japanese fish is a most important article of diet, and, what is to our Occidental minds most repulsive, raw fish eaten without a knife or fork is preferred. But poultry and other mixed food is by no means despised, and the army commissariat department was literally always to the fore in the late war in its efforts to obtain freshly-killed animals in preference to the tinned foods which had otherwise to be relied upon.

Vegetarians have not a monopoly of the quality of tranquillity, any more than the meat-eater of pugnacity. A parallel instance of the folly of rash generalisations occurred in the comparison made during a vegetarian lecture by an enthusiast between the odour emanating from the herbivorous animals' cages and that from the lion and tiger cages in the Zoological Gardens, much to the advantage of the former; but he was quite nonplussed when an auditor whispered loudly, "What about the monkey-house?" Despite this contretemps, however, it is an undoubted fact that diet has a marvellous effect on the odour of the fæces. Metchnikoff mentions a species of parrot in South America which lives on bananas, and whose fæces have the aroma of bananas, not being in the slightest degree offensive. With a well-balanced ration the odour of the fæces is by no means repulsive. Fatty acids resulting from the decomposition of carbohydrates are the natural stimuli of the colon, and as the action of proteolytic bacteria produces an alkaline medium, an excess of protein will neutralise or inhibit the formation of such fatty acids. The result is stasis of the colon and putrefaction with offensively smelling fæcal matter. There is little doubt that the fæces of a lacto-vegetarian will offend the sense of smell in a degree infinitely less than those of the average mixed feeder.

(7) The consumption of flesh is alleged to deaden the moral and intellectual faculties. I am not aware that the vegetarians can produce any more evidence of saintliness amongst their adherents than can be evidenced from a study of ancient Jewish records, and the attempts of Tennyson, Sir Walter

Scott, Benjamin Franklin, and Herbert Spencer to subsist upon a fleshless diet without success are by no means encouraging, and certainly do not warrant the statement that their intellect in any way suffered from their meat-eating habits. Both Franklin and Spencer are often claimed as adherents by vegetarians. It is quite true that Franklin in early life, partly for the sake of economy and partly on higher grounds, practised vegetarianism for about two years. Spencer discontinued the practice after six months' experience—long enough, in his judgment, to determine its suitability or otherwise, and the reason he gave for abandoning it was that his vitality was lowered almost to extinguishing point, as displayed by his lack of energy and inability to keep warm. His significant commentary on the nerve-feeding qualities of vegetables was to burn all that he had written during the six months.

It would, however, be quite unfair to condemn the lacto-vegetarian diet because of the inability of even such eminent men as Carlyle and Spencer to subsist upon it with advantage. If they had made a careful study of the fleshless elements of nutrition and selected them with care, there is no apparent reason why their experiment should not have been a success.

In an excellent review of the advantages of a fleshless diet, Hutchison criticises it for its lack of energy-producing qualities. He guards against the confusion of energy with muscular strength, and claims it as a property of the nervous system. He concludes: "Muscles do their work upon carbohydrates, but the brain appears to require nitrogen, which can only be obtained in a concentrated form from animal sources. If protein food, therefore, be regarded as a nervous food, a diet rich in it will make for intellectual capacity and bodily energy, and it is not without reason that the more energetic races of the world have been meat-eaters."

(8) The statement that it is difficult to convert a flesh-eater to Christianity, or even to humanity, is an example of the absurd arguments whose number is legion. It seems to be forgotten that Christianity was introduced amongst a notable flesh-eating nation, and that there are more Christians to-day in meat-eating England alone than there are in all the vege-

tarian countries in the world, although these include quite two-thirds of the world's population. It would be utterly futile to attempt to follow other contentions of a calibre similar to those which I have just named.

(9) The cereals and pulses are said to contain all the elements of nutrition without any poisonous ingredients. This is doubtless perfectly true, but it does not sound well in the mouth of those who are never weary of decrying flesh food because of its supposed poisonous purin content. Purins are purins, whether contained in vegetables or animal food, and when it is known that beans contain 1·5 grains per lb., oatmeal 3·46 grains per lb., lentils 4·17 grains per lb., and asparagus 1·5 grains per lb., it should serve as a warning to the flesh-abstainer to weigh his statements before uttering words likely to be used for his own condemnation. It has been urged that animal foods contain infinitely greater quantities of purins than those mentioned, and this is especially true of the glandular organs like liver, sweetbread, thymus, &c., but when we consider that cod has only 4 grains to the lb., mutton 6·76 grains, beef 7·9 grains, beefsteak 14·46 grains to the lb., most of which is in a free condition, so that it could, if necessary, be excluded during the process of cooking, this compares favourably with the 1·2 grains of methyl purin in every cup of tea and the 1·7 grains of the same substance in every small cup of coffee. The average flesh-abstainer who partakes freely of these beverages should exclude them from his diet list if he wishes to be consistent.

(10) It is stated that no one can possibly eat meat unless it is cooked and flavoured in such a manner as to disguise in some way its origin. But the same statement may clearly be made about vegetables and many fruits. Few vegetarians eat potatoes without the addition of salt, and fewer still like to be reminded of the horribly fœtid compost from which they obtained the elements of their growth.

(11) Nor is there much value in the argument from the æsthetic point of view. It loses sight of the fact that most meat-eaters admit fruits with vegetables and cereals into their diet, and hence the suggestiveness of summer and all its allied pleasures may be obtained by them as well as by the vegetarian. When the flesh-abstainer ceases his endeavour to

imitate the appearance and even the flavours of flesh foods it will be time for him to become enthusiastic over the beauty of his own food.

(12) The anatomical argument will not bear much investigation. A look at the teeth, which include cutting, tearing, and sharp grinding molars with clearly cusped edges, indicates their suitability for a mixed diet. If we differentiate the mammals according to their dietetic habits, we can classify them as herbivorous (including graminivorous), carnivorous, frugivorous, and omnivorous. We find that the human alimentary canal has individual characteristic features, although it is much more closely allied to that of the carnivora or omnivora than to that of the herbivora. It certainly presents some features of similarity to that of the frugivora, but not a sufficient amount to warrant the statement that man is frugivorous. Kingsford, whose investigation of the subject is deservedly held in respect by vegetarians, states that the length of the digestive canal, compared with that of the whole body, varies in the carnivorous races from three to six for one, whilst in the apes and man the proportion is seven to ten for one. This, of course, is an error, because that of man is in the proportion of only five to one, or just about half the length of the alimentary canal of the apes, and as the digestive tube in herbivora is from twelve to twenty-seven for one of the body length, it is quite out of proportion to that of man. It is of some interest to find that nations like the Chinese and Japanese, which have accustomed themselves to a diet containing large quantities of vegetables, have a slightly longer intestine than a nation in whose diet meat predominates. Many other items of Kingsford's comparison are equally valueless because founded upon inaccurate physiological data, as, *e.g.*, when she describes the movements of the stomach and finds a similarity to those in the frugivora, whereas our latest facts derived from Cannon make it pretty clear that the human stomach is certainly more like that of the dog and cat than she supposed it to be. Finally, for a definite period during early life all vegetarian mammals, whether from instinct or practice, but certainly by compulsion, depended on the animal proteins of milk, and were able effectively to reconstruct their tissue proteins from them.

Munk notes that the urine of man more nearly resembles that of the carnivora than that of the herbivora, and that his excretion of water approximates more decidedly to the carnivorous type. Thus in man 60 per cent. of the water is excreted by the kidneys and 40 per cent. by the lungs and skin. In the carnivora 70 per cent. of the water is excreted by the kidneys and 30 per cent. by the lungs and skin; whereas in the herbivora only 30 per cent. of the water is excreted by the kidneys, as compared with 70 per cent. by the lungs and skin.

Incidental Issues.—It is commonly asserted that the anthropoid apes live on fruits, nuts, and cereals, but this is not quite true, as they eat insects, worms, small birds, and such other animals as they can capture. According to Marcel Labbé, Professor Verneuil was unable to keep a young lemur in a healthy condition whilst in confinement, even though supplied with the finest of fruit, but it soon became strong and healthy when allowed to roam at will in a forest and supplement its frugivorous diet with the insects on the trees. With this observation to guide him he took it back to Paris and added raw meat to its usual diet, with the result that it remained in perfect health thereafter.

It is also quite certain that in captivity apes always succumb to tuberculosis without a supply of animal food. It is a remarkable fact that tuberculosis is rarely seen in carnivora, although, due to milk infection, it is frequent in the omnivorous pig, but it is quite common amongst cattle, chickens, pheasants, and turkeys. Would it be parlous to hazard the suggestion that the anthropoid apes have only remained as such from the lack or disuse of the weapon-using and house-constructing faculties which caused their troglodytic cognates to develop into man?

Whatever may have been the food of the anthropoid apes, it is really difficult to surmise that of primitive man, but if he originated in a tropical country, it is hardly to be expected that at first it would differ much from that of a frugivorous animal. But even if this statement, which is supported by Cuvier, Bell, Flourens, &c., be true, it is evident that for thousands of years now he has subsisted on a mixed diet, and that for many it is by no means an easy matter to alter

it. It is unquestionable that many find it most difficult to change to unaccustomed fleshless proteins and foods, and this is emphatically the case when they have not been prepared in some way to render their nutrient properties more accessible to the digestive juices. I do not doubt that the absence of the customary peptogens of flesh food has much to do with this difficulty, but I am bound to say that when I was in residence at Battle Creek Sanitarium I was astonished to find that out of the five hundred patients, most of whom had been previously living on the usual American diet of three meat meals a day, supplemented in many cases by large potations of alcohol and excessive indulgence in tobacco, an incredibly small number appeared to have any objections to, or to be affected in a deleterious manner by, the great change. I attribute this fact in a large degree to the careful preparation of the food, and especially to the almost invariable dextrinisation of the starches, so that the diastatic property of the saliva is utilised and nutrition thus benefited at an earlier stage than is usual.

According to Dr. Kellogg, the essential feature of the diet at Battle Creek was that it was antitoxic, by which he meant that it contained no substance, nor any ingredient, likely to be converted into toxin in the alimentary canal and so produce auto-intoxication. It was decidedly a low-protein diet, and was constructed as nearly as possible of 10 per cent. protein, 30 per cent. fat, and 60 per cent. carbohydrate. It was likewise purin free, no beverage except milk, a variety of curdled milk called yogurt, apple juice, grape juice, water, and a sample of scorched cereal preparation to resemble coffee being allowed.

Many of the benefits alleged to be due to a fleshless diet are clearly incapable of being demonstrated, and may indeed just as well be due to the low protein content or the extreme moderation. Kellogg has lived in a community of flesh-abstainers for forty-five years, and for forty of these years has made careful note regarding the incidence of cancer amongst them. In all that time he has only known of two instances of cancer in flesh-abstainers, one case in a woman of fifty years of age, the other in a man. This latter was melanotic sarcoma of the eyelid, which was removed and

recurred just in front of the ear about four years ago. Since this was removed by excision, the patient has remained well. He reports one authenticated case of a flesh-eater who had epithelioma at the back of the neck. He states that "a cure occurred about four years after the man had changed his habits of life by becoming a flesh-abstainer, sleeping out of doors and taking a considerable amount of daily exercise. Such a case is, however, not unprecedented, as spontaneous cure of undoubted cancer has occurred in cases without any such remarkable alteration of the daily life. Rogers Williams states that negroes in Africa on practically any diet were quite exempt from this malady, and that even after transplantation to America, where they were subjected to excessively hard work and a very frugal diet, the disease was by no means common. When, however, slavery was abolished and they adopted more luxurious habits, they became equally prone to cancer with the people of the United States. The cancer mortality of the negroes in South Carolina, where they live on a simple diet, is 12 per 100,000, while whites are dying at the rate of more than 150 per 100,000. In Chicago, however, the mortality of the negroes is greater than that of the whites.

Precisely the same experience was noted in connection with tubercle. In their wild condition, subsisting on an undoubtedly mixed diet, the Red Indians of North America knew nothing of tubercle, whereas now, in the midst of civilisation, one out of every four succumbs to the white plague.

On the other hand, evidence is daily accumulating that on a simpler diet of fruits, nuts, and cereals, drunkenness is practically impossible, and that adoption of this diet is almost always followed by a cure. There is also a disposition to give credence to the statement that appendicitis is practically unknown amongst vegetarians. Lucas-Champonnière in an analysis of 20,000 patients among Roumanian peasants, who live chiefly on vegetables, found only one case of appendicitis, whereas the proportion amongst city-dwellers in Roumania—the diet being of a mixed character—was one case among every 221 patients. Owen Williams asserts that this is to be attributed to the excess of saturated fatty acids in a meat diet as compared with the unsaturated fatty acids

in a vegetable diet, the former being less easily absorbed and liable to be deposited in the submucosa, thus cutting off the blood supply to the mucous membrane and so rendering invasion by organisms an easy matter.

It is often thought that on a fleshless diet sexual desire is not nearly so great, but I think that this is a question of the amount, rather than the kind of protein. I hardly think that the dog is the most prurient of animals. I should say that distinction must be reserved for the rabbit, and it is notorious that sexual precocity is fairly common among herbivora. I know of two vegetarians whose sexual desire almost amounts to satyriasis, and the frugivorous habits of the Japanese do not seem to have relieved them of the *koshiwara*.

It is reported that the new system instituted amongst the Yale undergraduates of permitting them to select their own items from a carefully prepared menu has resulted in a practical low-protein system obtaining amongst them, and it is stated that this has diminished immorality amongst the students. Dr. Chalmers Watson points out that excess of animal foods produces changes in the mammary glands of all pregnant animals, and asserts that this induces inability to nurse the offspring, and is one cause of the physical deterioration which is creating such anxiety in this country.

Dr. Rymer has shown that in a large experience amongst vegetarians, the tendency is for the teeth to simulate those of the herbivora and lose their cusps, and Dr. Kaufmann, of Birmingham, has observed that children who profess an aversion for meat are very apt in after life to become tubercular.

Kellogg's Case for Vegetarianism.—Although Kellogg in his drawing-room lectures does not scruple to employ many of the questionable arguments in favour of vegetarianism to which I have just referred, he never relies upon them in discussion with scientific men. In such an encounter he would first annex all the advantages claimed by the low-protein theorists, and would then turn to his study of the question as presented before the International Congress on Tuberculosis at Washington in 1908. The facts there presented are undoubtedly most powerful arguments in favour

of a low-protein fleshless diet, so far as they go. From thirty years' observation on thousands of patients and attendants in Battle Creek Sanitarium, he contends that the following advantages are rapidly brought about:—

(1) Clearing the skin, disappearance of skin eruptions, sallowness, &c., and rapid improvement in colour and texture of the skin.

(2) Improvement in the blood count and in the hæmoglobin, 12 per cent. in the former and 15 per cent. in the latter.

(3) A notable fall of blood-pressure, from an average of 181 mm. Hg to 158 in a fortnight's time.

As no pressure-lowering drugs were administered, he attributed this fall to the suppression of pressure-raising toxins produced in the alimentary canal, and to the better elimination of waste tissues. Professor Zuntz, of Berlin, demonstrated that protein requires a much greater expenditure of energy in its digestion and utilisation than the other food principles. The energy required for the digestion of fats is only $2\frac{1}{2}$ per cent. of the total energy represented, whereas that required for starches is 10 per cent., and that for protein is 16 per cent. The burden thrown upon the liver and kidneys by excreting the excessive quantities of urea and uric acid on a high-protein meat diet is at least four times greater than that on a low-protein fleshless one, and there is a marked diminution of the alkalinity of the blood. This results in deficient oxidation of the protein and accumulation of waste products in the blood and tissues. These are of a highly complex character, taxing the kidneys, liver, adrenals, thyroids, and other organs; whereas the metabolism of fats and carbohydrates, he declares, simply produces CO_2 and H_2O , which are easily eliminated without harm.

He conducted many experiments and made many analyses of excreta, showing that intestinal putrefaction is directly proportional to the amount of protein in the dietary, as much as twenty times the amount of indol in the fæces and indican in the urine being produced by low-protein fleshless feeders who were put on a high-protein meat diet. At the same time they displayed symptoms due to this increase of protein, such as headache, loss of appetite, loss of energy, and general malaise. A striking table is presented showing the amount of indol pro-

duced in equal quantities of various food-stuffs (25 grams) mixed with 10 grams of human fæces and incubated for three days. The figures were an average of 854 mg. of indol for meats, 1.045 for milk products, 0.181 for vegetable foods, whilst cereals were 310 times less toxic on this method of examination than mutton, which, strange to say, was the most toxic flesh food.

Breisacher has shown that the removal of the thyroid gland of a dog is quickly followed by death if the animal is fed upon a meat diet, whilst life is indefinitely prolonged, and the animal enjoys good health, when fed upon a diet of bread and milk. Blum and Kishi hold that the function of the thyroid gland is to neutralise the poisons derived from the putrefaction of albumin in the intestine.

In the ingenious Eck fistula experiment an anastomosis is made between the portal vein and the vena cava, a ligature being applied to the portal vein close to the liver, thus cutting out the liver from the portal circuit. A dog thus prepared, fed upon meat, dies in three days; when fed upon bread and milk the animal lives in excellent health for an indefinite length of time. Pavlov has demonstrated that the urotoxic coefficient of such a dog is trebled after tying the portal vein, showing that the liver has three times as much work to do on a high-protein flesh diet as on a low-protein fleshless diet.

Hirschfield has shown that with a diet of 70 grams of albumin a healthy kidney eliminated 10.8 grams of nitrogen, a diseased kidney 9.3 grams. When the albumin ration is increased to 130 grams the healthy kidney eliminates 14.5 grams and the diseased kidney only 11.7 grams, and this disproportion increases the longer the high-protein diet is maintained.

Flesh foods contain on an average 200,000,000 putrefactive bacteria in every gram, so that an impressive total must be swallowed in the course of a day. Fortunately for us, as has already been pointed out, Nature has not left us to the tender mercies of all these virulent toxins, and thus we must recognise efficient reasons why auto-intoxication does not exist in healthy persons, even although all the local conditions may be present in them. Where, however, hypochlorhydria is present, or the colon is catarrhal, or the liver and thyroid and other glands are

defective in their activity, toxins are liable to be admitted into the blood and exert their malign influence in the body.

The Social Movement.—The powerful advocacy of enthusiastic men like Kellogg, however, is by no means futile. An enormous conversion of public opinion in favour of a fleshless system of feeding is to be observed in the Western Hemisphere. In spite of this, however, meat-eating on the whole is on the increase, and so the price of meat has risen, although probably the influence of the great Trusts has something to do with this. The daily ration of meat issued to the Japanese Army during the Russo-Japanese War must have whetted their appetites for meat, and in this way, perhaps, set the fashion for its increased use in Eastern nations.

But, after all, this experience is precisely what might have been expected, for be it noted there is a tendency to diminish the consumption of meat in nations where an admittedly excessive quantity was being consumed, and to increase the consumption in nations where previously it was not used at all, or only in minimal quantities. So long as the amount of meat in the daily diet is not greater than can be coped with by the digestive and excretory organs, I cannot see that any harm is likely to accrue to the body, and if no damage arises there is no doubt that a greater degree of vitality and vigour will be exhibited.

In reading the literary columns of the vegetarian journals one cannot help being struck with the fact that the greatest number of converts will be found amongst people beyond middle age, and the glowing accounts of the improvement in their health must be attributed to the diminished demand upon the organs of excretion.

The Personal Argument.—Despite all that has been said, therefore, the only infallible argument in favour of vegetarianism to-day that has the slightest value for the individual is the personal one, to which there is no answer. When a man says that he can exist in perfect health and full possession of his faculties on a fleshless diet, then it is pretty clear that it suits him, and he would be foolish to add flesh if he, for any reason, objected to it. But this is the only reason against a moderate use of flesh food which demands serious consideration.

At the same time we have abundant evidence at our disposal

to show that a lacto-vegetarian diet is not only capable of maintaining health, but apparently imparts more endurance than one with a large proportion of flesh in its composition; while even with a carefully selected pure vegetarian diet life and health are not only possible, but in some these attain a higher degree of worth than on any other diet.

I am not inclined to state the case with more emphasis than this, because I do not think that sufficient proof exists to show that flesh in moderation is necessarily productive of intestinal auto-intoxication. It has no obvious influence in this direction in the average mixed feeder, although one cannot view the yearly increasing proportion of deaths from chronic diseases in any civilised country without reflecting that, conjoined with sedentary habits and intestinal inactivity, it may be a factor in the incidence of such ailments.

The chief value of the practice of vegetarianism is the inculcation—tacit or expressed—of the principle of moderation. Those who depend for their nutrition on the ordinary fleshless foods as prepared by Nature may indeed consume more than the mixed feeders, but as hardly more than three-fifths of this amount is utilised, they obtain all the advantages of a moderate diet, and if they possess vigorous digestive organs even these are likely to share in the benefit. When, on the other hand, their alimentary canal is not up to the standard of capacity for dealing with a large quantity of ballast, dyspepsia in one form or another is likely to arise, and in the end malnutrition may supervene.

Those flesh-abstainers who are sufficiently well versed in the tenets of up-to-date vegetarianism will make use of the many excellent manufactured fleshless foods now obtainable, the feature of which is their concentrated and partially digested character, and they are intelligent enough to refuse to burden their digestions with an excess of useless material.

At the same time it is advisable that vegetarian foods should not be subjected to excess of refinement in their manufacture, or else their natural cellulose may require to be supplemented by an artificial addition in this direction.

CHAPTER IV

LOW-PROTEIN THEORY AND PRACTICE

HAVING discussed in a fairly comprehensive manner the most ancient of all theories of diet, we have paved the way for a consideration of the most recent arrival, viz., the low-protein theory, and as in many respects there is a notable degree of similarity between the two, our deliberations upon it need not be at any great length.

It has always been known that moderation in eating and drinking was decidedly advantageous, but whilst admitted in theory its practice was confined to a few. The classical case of Cornaro will occur to every one. A physical wreck at the age of forty, he adopted a system of extreme temperance in eating and moderation in drinking, partaking of only 12 ounces of mixed food daily and 14 ounces of red wine, gradually diminishing this quantity as he grew older, and died peacefully in his own armchair at the age of one hundred and three.

Even before the days of Cornaro there are many examples of parsimony in diet, for Cyrus, the creator of the Persian Empire, subsisted from childhood on the simplest and plainest diet of vegetable food and water, whilst his soldiers adhered to the same rigorous fare. Coming to our own day, we find Edison telling us that for two months he lived on 12 ounces of food per day, taking absolutely no exercise and retaining his weight at 185 lbs., while Dr. Rabagliati in our own country has been preaching for many years that no man should eat more than a pound and a half of food per day, and he, personally, restricts his allowance to nearer 12 ounces. These, however, have been looked upon as

exceptional cases, and as there was no scientific precision used in the measurement of their diet, they can hardly be recognised officially.

Besides, until the last few years, it was always considered that however much the total quantity of the food might be diminished it was dangerous or at least risky to curtail the allowance of the tissue building and repairing protein. Voit's diet of 118 grams protein (105 grams of which must be absorbable), 56 grams of fat, and 500 grams of carbohydrates with a total fuel or caloric value of 3,050 large calories, was considered essential to keep the body in equilibrium. Moreover, under conditions of hard work the Voit standard increased the daily allowance to 145 grams of protein, with fat and carbohydrate sufficient to yield a total fuel value of 3,370 calories. Other experimenters in various countries, notably Atwater in America, who fixed the daily protein requirement at 125 grams, with sufficient fat and carbohydrate to produce 3,500 calories, obtained very similar results, and emphasis was laid upon the fact that it was hazardous to transgress below these limits if health and strength were to be maintained. These deductions were made from observations on the customs and habits of mankind, which—even in highly civilised countries—are by no means always in accordance with physiological laws, but "orthodox physiological faith" was soon established on the pronouncement, and it was considered that this settled the matter. This, of course, it did, so far as it showed the dietetic standards arrived at empirically by mankind, but it in no way demonstrated what were the actual requirements of the body. As a matter of fact, in 1887 Hirschfeld remained in nitrogenous equilibrium for nearly a fortnight on about 6 grams of nitrogen, as opposed to his usual diet of 16 to 20 grams per day. The diet on which he subsisted was practically of the lacto-vegetarian type, and the above amount represented about 40 grams of protein with, in addition, proportionally increased quantities of fat and carbohydrates. In 1889 E. Voit, studying the diet of vegetarians, found that with 8 grams of nitrogen or about 50 grams of protein and augmented allowances of starch and fats, it was possible to maintain nitrogenous equilibrium. Klemperer, Caspari, Breisacher, Siven and

other workers have made similar experiments and arrived at similar conclusions, all deliberately proving that it is quite unnecessary to consume a diet of high protein-content in order to establish nitrogenous equilibrium.

Such experimental diets having demonstrated that life was perfectly possible on a smaller quantity of nitrogenous food than was contained in the standard diet, the question then arose as to whether it might not be more advantageous to the health thus to subsist, Voit himself having enunciated the principle that the smallest amount of protein with the addition of fats and carbohydrates that would maintain the body in health and vigour is the best conceivable diet. He recognised that an excess of non-nitrogenous food would be unlikely to damage the tissues because its end-products, being carbonic acid and water, were comparatively harmless, whereas the ultimate results of protein metabolism were highly irritating products, which were liable to injure the body both functionally and organically. The chief reason, however, for concentrating the attention upon the protein requirement was that it is now known that it is not a variable modified by the amount of bodily activity, as is the case with fats and carbohydrates, but a constant for the individual, dependent mainly upon the weight of the protein-containing tissues of the body and the waste of their protoplasm. The amount of nitrogen excreted is, of course, a measure of this tissue waste, but the problem is complicated by the fact that it is increased in accordance with the quantity of protein food consumed, and hardly at all influenced by the degree of bodily activity. These two facts clearly demonstrate that protein is not the source of the energy of muscle work, and that it is incapable of being stored up in the body to any appreciable extent; and a reasonable deduction to be inferred from these statements is that any excess of protein food above the quantity actually required for the repair of the waste of the tissue cells is superfluous and uneconomical, expending the energies of the body in an entirely unnecessary manner, and exposing the tissues to wanton damage from an excess of nitrogenous waste products.

Chittenden's Experiments.—Reflecting upon these facts and fully believing in the principle of moderation, Professor

Chittenden determined to put the question to the test of scientific experiment. His attention had been directed in 1901 to the mastication experiments of Mr. Horace Fletcher and Dr. Van Someren, who at their own instance had submitted themselves to the observation of Sir Michael Foster with the object of proving the revolutionary contention which they made that the average man was eating twice too much food. They had the gratification of demonstrating that careful mastication had made the appetite more discriminating, had diminished the total requirement of food by one half, and in particular had caused a reduction of the protein ration by quite two-thirds. In 1902-1903 Mr. Fletcher spent several months with Chittenden, and showed that he was able to maintain his body weight of 75 kilos and perform the work of a trained athlete in the gymnasium on about 43 grams of protein.

Being now thoroughly satisfied that the observations of Voit and others on the dietetic habits of the people had failed to establish the true physiological requirements of the body, Chittenden determined to institute a prolonged experiment of his own, and in this he was fortunate in having the co-operation of the United States Government and the Carnegie Institute. His aim was to demonstrate the true nutritive requirements of the body as contrasted with the dietetic habits, and he insisted that during the experiment the following four points should be carefully kept in view :—

(1) That nitrogen equilibrium be maintained, thus ensuring that no excessive acid waste products of protein metabolism were created to irritate the tissues and that no demand was made upon the tissues themselves to produce the nitrogen required for nutrition.

(2) That physiological equilibrium be maintained, *i.e.*, that the body weight should not be reduced.

(3) That physical efficiency be maintained.

(4) That the body should retain its power of resisting disease.

The subjects of the experiments were (1) five brain-workers (University professors and instructors), (2) thirteen men who volunteered from the Hospital Corps of the U.S. Army to represent the moderate muscle-workers, (3) eight

University athletes, all thoroughly trained, and who worked hard both mentally and physically. From October, 1903, to June, 1904, 225 days in all, these men submitted to have all their food and drink carefully weighed and measured, their daily excretions analysed, and at stated times their "nitrogen equilibrium" ascertained. On account of the reasons already given, the problem was narrowed down to the discovery of the smallest quantity of protein necessary for nutrition and the maintenance of health.

Results and Observations.—It will not be essential to enter into the details of the investigation, which can be read in Chittenden's personal narrative. It is sufficient to record that he himself, a man of 57 kilos body-weight, maintained himself in nitrogenous equilibrium and greatly improved his health on 36 grams of protein, while his total daily diet measured no more than 2,000 calories. Dr. Mendel, who weighed 70 kilos, was responsible for the ingestion of 41 grams of protein per day and food of a total fuel value of 2,500 calories, and the three other brain-workers in like proportion.

The members of the soldier detachment lived without discomfort for a period of five months on amounts of protein food not more than half of that considered necessary by standard dietaries, or about 50 grams, and the average for the athletes was 55 grams. But this dietetic restriction not only succeeded in fulfilling the four principles laid down by Chittenden, but also effected a notable improvement in the health, and their strength was so greatly augmented that dynamometric mensuration recorded an increase of quite 50 per cent.

It will be seen that these results were effected without in any way supplementing the other elements in the diet, and a scrutiny of the items in the menu fails to discover that any restriction was practised as regards the nature of the protein. It is also of importance to note that no kind of food or food-accessory was prohibited or prescribed, although, the object being to live on the smallest possible quantity of protein consistent with health and vigour, flesh foods were naturally reduced to a minimum. There was likewise a noteworthy diminution in the total quantity of the food. Chittenden's whole allowance for the day only weighed 1 pound 6 ounces,

about two-thirds of what the average man takes three times a day. The athletes consumed very little more, while the soldiers, instead of their customary 75 ounces of solid food and 3 pints of coffee, took only 51 ounces of solid food and $1\frac{3}{4}$ pints of coffee, and instead of 22 ounces of meat in their former dietary they were now content with only 1 ounce daily. As a result of this experience Chittenden therefore crystallised his views on the dietetic problem in the statement that he believes in a low-protein mixed diet for the following reasons :—

(1) Because he coincides with Folin and others in the view that no nitrogen can be stored up in the tissues.

(2) Because energy is dissipated in excreting the surplus protein.

(3) Because excess of protein tends to disseminate toxins throughout the body.

(4) Because there is no necessity to indulge in muscular exertion to aid in working off surplus protein, and hence energy is saved.

(5) Because a combination of animal and vegetable proteins is essential for the requirements of the body.

There are only two arguments which could be reasonably urged in opposition to these conclusions, and neither of them is tenable: (1) that the excess of protein food is consumed solely for the sake of its carbonaceous molecule, which may play some part in the organism that the ordinary non-nitrogenous foods cannot play; (2) that the excess of protein food is required for its stimulating effect upon metabolism. The former proposition has so far obtained no adequate support, and the latter is a double-edged weapon, for it may very properly be objected that all undue stimulation is unphysiological and deleterious to the best interests of the body.

Hence from the results of his experiment Chittenden concludes that the daily protein requirement of an adult receiving a sufficiency of non-nitrogenous food to supply the energy demands of his body is .85 gram per kilogram of body-weight, equal to an excretion of .12 grams of nitrogen per kilogram. A man weighing 70 kilograms, or 154 pounds, would therefore need 60 grams of protein food daily, equal to one half the Voit standard, much less than the Atwater standard, and infinitely

below the ordinary consumption of protein food in Europe and America as indicated by the published dietary standards.

Critical Aspects.—Whilst the facts I have just detailed are incontrovertible, and form in themselves a powerful argument for moderation in eating and drinking, there are not wanting critics who assert that the experiment was not continued for a sufficient length of time, and who even place quite a different interpretation upon the results. It should be noted that in every case without exception there was an initial fall of body weight to a fixed point, at which it remained stationary, and it is pointed out that if one is satisfied with such a diminution of the weight and with a lessened heat production, economy is quite possible in the diet. This, of course, admits that the standard diet based upon custom is really in excess of the bodily requirements. But now that food supplies and clothing are so easily obtained, fat is not so necessary as a reserve store for the production of heat and energy. It is also asserted that protein may be diminished greatly if taken along with carbohydrates and fat, because the last two act as "protein spacers." Although at all times the tissue cells seize upon protein in preference to any other nutrient, this statement is diametrically opposed to the views held by Folin, who contends that the greater part of the protein is metabolised with the sole object of obtaining its carbonaceous molecule. It is also pointed out that a vegetarian diet with protein and carbohydrates intimately mixed, so that they reach the tissues at the same time, is one that lends itself to the maintenance of nitrogen equilibrium on a relatively small amount of protein.

On the plea that in such matters Nature is far and away the best guide, attempts have been made by instituting a comparison between the diet at a time before artificial dietetic habits have been formed and there has been any stimulation of the appetite, viz., the proportionate ingredients of a suckling infant's food and those of the food when the full period of growth had been attained, i.e., presumably after fixed dietetic habits had been established, and by this means establishing a fixed standard for guidance throughout life. It has been computed, for example, by one method of calculation, that as an infant of six months old only consumes 14 grams of protein daily, on the same basis an adult should only require

about 70 grams, which is practically what Chittenden contends. Comparisons of this nature, however, lack impressiveness, because an infant seven days old and weighing $8\frac{1}{2}$ pounds consumes 400 grams of breast-milk daily, yielding 8 grams of protein. This is equal to 2.07 grams per kilo of body-weight, an amount hopelessly in excess of Chittenden's standard. Without making any effort to reconcile those figures, it is obvious that the protein requirements of the infant and growing child must be proportionately greater than those of the adult, because the latter only needs protein to supply the natural waste of tissue and losses by the secretions, while the former demands in addition an extra quantity to build up the developing tissues. As if to make confusion worse confounded, Rubner, strange as it may appear, has in recent years entered the lists as a champion of the doctrine of a low-protein diet for infants. He states that "in the maintenance diet of suckling infants only 5 per cent. of the calories are derived from protein, 95 per cent. being furnished by fat and carbohydrates," and that if a food equally as suitable as milk were available for adults it would be quite possible for them to live comfortably on equally small quantities of protein, suggesting 31.4 grams as the limit. I do not pretend to explain doctrines apparently so irreconcilable, but consider them worthy of mention as betokening the remarkable interest which has been aroused on the subject.

Benedict's Views.—The most critical examination of the low-protein theory is that published by Dr. Francis G. Benedict. He categorises Chittenden's dietetic study on himself as the most remarkable on record, and declares that "nowhere in the literature of nutrition do we find an experiment so painstaking and accurate, covering so long a period," viz., two years—and I can personally vouch for the fact that he subsists on a similar diet to-day—"and with a diet of so low a protein-content following a normal diet." It has been justly cited as a "monument of fidelity." Whilst, however, agreeing with the accuracy of his data, and praising him in no unstinted terms as a faithful student of nutrition, he is inclined to doubt his deductions, and hints that mental suggestion may have had much to do with the good results obtained. He considers also that much of the benefit to the health was due to the regular life

and unique form of social communion in vogue, and asserts that the daily supervision of Dr. W. G. Anderson, the well-known Director of the Yale Gymnasium, could not fail to be an important factor in the experiment.

He wonders whether the abnormally low protein did not occasion some disturbance of the alimentary tract, affecting its power of absorbing either the protein of the food or the nitrogenous materials from which the so-called metabolic products are derived, such as is said to occur in animals under similar circumstances, although this is hardly in agreement with his own statement previously referred to, that protein in common with the other alimentary principles is absorbed in proportion to the amount which has been ingested. His speculation on this point has been in great measure answered by Chittenden's most recent lengthy observations on six men varying in age from 21 to 29 years, and in weight from 51 to 70 kilograms. These subjects had absolute freedom of choice in their diet, except as regards meat, which was somewhat restricted, and were found to have an average daily intake of 75 grams protein, as contrasted with the Voit standard daily intake of 118 grams, and a daily consumption of 8-9 grams of metabolised nitrogen in place of the 16 grams in Voit's scale. The most careful examination was made to discover whether the lowered intake of protein food had produced any recognisable metabolic changes, but the results were entirely negative in character. As a relatively large amount of fat was consumed, the conditions were favourable for showing even a slight impairment of the digestive functions, but even although the diet necessarily contained a large proportion of vegetable matter, the utilisation both of nitrogen and fat was quite up to the standard in healthy individuals. Not only so, but as the experiment progressed the utilisation of nitrogen and fat showed a tendency to increase rather than decrease. The observations were continued for 130 days, and during this time the utilisation of nitrogen varied from 88 to 90, that of fat 97-98 per cent., while all the subjects showed continuously a plus nitrogen balance, irrefutable evidence that the daily protein consumption was quite adequate to meet the needs of the body. Besides this, a gain of weight, varying between a quarter of a pound and 6 pounds, was

displayed by all the subjects, and the men were noted to be in better general condition at the conclusion of the test than they were at the beginning.

He thinks it is difficult to understand why the men, especially the athletes, should have returned afterwards practically to their former diet, considering the improved physique they obtained, and can only explain this on the assumption that they were obsessed by an irresistible craving for more protein food. He controverts the statement that large quantities of protein food are liable to damage the kidneys, and points out that athletes who habitually consume excess of protein during training have no difficulty in excreting all the waste products without harm, nor are they liable to be hampered in their activities or grace of moment by gouty or rheumatic infirmities. When large quantities of pure water are administered to patients there is no obstacle to its excretion by the kidney. It is indeed more reasonable to suppose that a more concentrated urine of high specific gravity would impose greater strain upon the kidneys. The lungs have no difficulty in augmenting their excreting capacity, and the kidneys are not likely to be in a different category.

He proceeds to give details of other investigations, from a consideration of which one must infer that a reduction of the protein content is directly hostile to the best interests of the body. These observations cover a wide field, are comprehensive in character, and quite emphatic in their deductions. Experiments upon carnivorous, omnivorous, and herbivorous animals are cited which demonstrate the danger to life and health attending the diminution of the protein ration. Munk, Rosenheim, and Jägerroos have all concluded that a lessening of the protein in the diet of the dog is invariably attended by rapid exhaustion, and if unduly persisted in, death supervenes quite suddenly. This they attributed to a degradation of the epithelial cells of the intestinal canal inducing a loss of the power of absorption, as well as to a diminution in the secretion of the digestive fluids. These bad results are ascribed by Chittenden to the monotony of the diet employed, and he has with the assistance of his coadjutors at Yale conducted a series of experiments, the results of which controvert the conclusions arrived at by the investigators just mentioned. The dogs

remained in good health, maintained their strength, increased their weight, and continued in nitrogenous equilibrium on less than two-thirds of the protein which caused the death of the animals under Munk's observations. He is at present engaged in further researches on the effects of low-protein diet on dogs, and we await with interest the publication of his results.

The flesh of hogs fed on either an excessively low or an excessively high protein diet is characterised by "softness." Reduction of the protein, as, *e.g.*, by administering Indian corn, produces pork of a very inferior quality, and an alimentary canal of abnormal friability when dressed. These animals must be indeed very susceptible to any alteration in their diet, for a slight increase in the protein ration results in their return to a normal growth and a healthy condition.

Another well-known experiment made at the Experiment Station of the University of Minnesota by Professor T. L. Haecker is detailed, in which two groups of ten cows each were fed, the one on the usual diet and the other on a low-protein ration, for three years. At the end of two years the latter group had lost weight, but their physical tone was good. In the third winter, however, they began to fall off in flesh and their coats became exceedingly harsh, a recognised indication of malnutrition, so that it became necessary to increase the protein. This experiment should be contrasted with that recently reported from the University of Wisconsin on the protein requirements of dairy cows. The authors state that, on an average, rations of medium protein-content proved more economical and more effective both absolutely and relatively for dairy cows than rations of a high protein-content, such as approach the German standard rations.

Benedict rightly infers from these experiments that "men may subsist for six months or even longer on a low-protein diet without serious disturbance of the alimentary tract or of nutrition in general." He points out, however, that from an examination of the faecal evacuations of the soldier squad there was considerable evidence of wide variability in the quantity of the faecal nitrogen, as much as a quarter of the amount ingested being excreted instead of about one-ninth, which he himself had previously determined was the normal amount.

General Considerations.—Other objections that might be

urged against a low-protein diet relate to a comparison of the general dietetic habits of successful nations and races of people as compared with the illiberal allowances of inferior and unsuccessful races, and it is notable in this connection that Italians from the northern provinces, as well as the Japanese, by adopting a high-protein ration on their advent in America, markedly increase their working capacity. As I mentioned in the last chapter, it has been frequently asserted that the Japanese subsist on a low-protein vegetarian regime, and the performances of their jinricksha men are truly cited as wonderful feats of strength. But Professor Oshima, who made a very careful study of this subject, clearly established the fact that the diet of the jinricksha men contained a much larger quantity of protein than was proposed in the Voit diet.

Much more recently Colonel Melville conducted an experiment on twenty infantry soldiers, to determine, on a measured quantity of mixed food and a definite amount of work, the effect on the health and well-being of the men. For six consecutive days they marched 13 miles each day, then had one day's rest and marched 13 miles on five further consecutive days. During the first week each man consumed on an average 190 grams of protein, 510 grams of carbohydrate, and 58 grams of fat each day, and during the remaining part of the experiment 145 grams of protein, 450 grams of carbohydrate, and 110 grams of fat daily, making a daily average for the whole period of 168 grams of protein, 480 grams carbohydrate, and 84 grams of fat. This amounted in all to 3,481 calories, or, with 10 per cent. deducted for loss in the excretions, an available daily food supply of 3,140 calories. Briefly, the result of the experiment showed a gain of weight for the first three days, which could only have been attributable to a retention of water, of which a liberal allowance was drunk, a maintenance of the weight for the next two days, and then a steady fall of weight for the rest of the time. The average fall of weight per man was 1.22 kilos, or a calculated daily loss of 60 grams of fat and 170 grams of flesh, the effect of which was visible in the sunken eyes and hollow cheeks of the men. Quite evidently the men had been subsisting on an amount far short of their nutritive requirement, which was estimated by Melville at 190 grams of protein, 480 grams of carbohydrate,

and 150 grams of fat per man per day, an amount well over 4,000 calories.

Most of those engaged in the discussion which followed the reading of Melville's paper at the annual meeting of the British Medical Association in London, 1910, agreed that the quantities were none too much, but emphasis was laid on the fact that quality of protein was of profound importance. Dr. E. P. Cathcart mentioned that Michaud had demonstrated this in his experimental feeding of dogs on dogs' flesh, and from this point of view, in human feeding, cannibals possessed really an overwhelming advantage. Carbohydrates were stated to be valuable not only in the rapid supply of energy they furnished, but because they played an intimate part in the metabolism of protein tissue. As during the march the lumbar muscles increased in bulk, protein was necessarily stored up, although their water-content was clearly responsible for four-fifths of this increase in size.

It was pointed out by others that too much stress could not be placed upon habit in the selection of food as a justification for the quantity consumed, and it was suggested that man's natural diet contained the following proportions of alimentary principles: .8 of proteins, 2 of fat, 3 of carbohydrates and .5 of mineral salts. Such a proportionate estimate, however, is purely empirical, and must necessarily vary with every alteration in the expenditure of energy, but it is evident that from such a short experiment, without careful training by a cautious and gradual reduction of the ingredients of the diet, it is hardly safe to draw conclusions as to the nutritive requirements of the body. It is fairly clear, however, that severe exertion instituted for a short period in men accustomed to a liberal dietary demands an increase in their daily rations. It is equally certain, from observations other than those of Chittenden, that if the body is kept in good training it is quite possible to lower the diet to two-thirds of Voit's standard, and yet find that the muscular strength and the power of carrying out work are actually increased.

In their efforts to uproot beri-beri, the Medical Bureau of the Japanese Navy commissioned a battleship to make a long voyage, the men receiving the usual naval ration of 91 grams of protein per day. The contrast between the enor-

mous number of cases of beri-beri amongst the marines and the better-fed officers led to another battleship being sent on precisely the same route with a protein ration of 155 grams per day, with the result that this latter ship had infinitely less sickness than the former. This large quantity is now established by law as the Japanese sailor's allowance.

In a conversation with Chittenden on this subject, he contended that it does not necessarily follow that the improvement in the health of the crew was due to an increase in the amount of protein *per se*. He thought it was much more likely that other elements were introduced into the food capable of accounting for the disappearance of the disease. Protein pure and simple is unlikely to be utilised as a food in the body. It is much more likely that it requires to become a salt of lime, potash, or soda before it can be available for dietetic purposes. He thinks that the mineral salts introduced with the protein prevented beri-beri much in the same way that lemon-juice prevents the appearance of scurvy. He also combated the view that a diet rich in protein was likely to increase the resistance to disease. Dr. Reid Hunt, of Washington, fed two groups of dogs on a high and low protein diet respectively. Acetonitrile was then administered to each group, and it was found that the low-protein dogs could withstand a three times larger dose than the others, hence proving that they had a greater resistance to morbid influence.

Although Benedict very generously agrees with regard to these two observations that probably some factor was in operation to obviate the occurrence of the beri-beri other than the protein, he quotes some other experiments pointing to a different conclusion than that arrived at by Reid Hunt. Whilst he is inclined to modify his views slightly as regards some of the minor arguments against the low-protein diet, he believes that "the following observations militate against the view that a material reduction of protein in diet is desirable:—

"(1) From the results of the digestion experiments with the reduced diet on the soldiers, it is seen that abnormally low protein may affect the absorption of nitrogenous material from the alimentary tract.

"(2) Animals fed on diets low in protein do not thrive so well as on normal quantities.

"(3) Dietary studies all over the world show that in communities where productive power, enterprise, and civilisation are at their highest, man has instinctively and independently selected liberal rather than small quantities of protein."

"Energy Requirement."—Benedict has, however, contributed a much more valuable argument in favour of a liberal supply of protein from direct observation of subjects at rest and at work in the large respiration calorimeters he has installed in his laboratory. He believes that it is quite possible to live on a low-protein diet, but not that a sufficient supply of energy can be manufactured without a very much larger supply of food than is maintained by either Kellogg or Chittenden. He states that it is only necessary to know the daily energy output to determine the energy requirement, for the energy output is practically the energy requirement. He finds that a man of average size, weighing 66 kilograms and at rest within the calorimeter, has an energy requirement for twenty-four hours of not far from 2,270 calories. Naturally the average individual outside the calorimeter, pursuing his ordinary course of life but not engaged in any occupation, would actually require more than this, because with the greater liberty to move about, the movements of the body would call for the utilisation of more energy.

It is interesting to know that he subjected Mr. Horace Fletcher, who was the first man upon whom Chittenden experimented, to a calorimetric test. From the study of Mr. Fletcher's diet Chittenden came to the conclusion that Mr. Fletcher was able to hold his own with 1,700 calories of energy. During this period he was undergoing an unusual amount of muscular exercise with the Yale University crew, and yet on a small quantity of food not only was nitrogen equilibrium maintained, but his body-weight also remained practically unchanged. During the three days of residence in the respiration calorimeter, his average output of energy was 1,896 calories, whereas the amount of energy actually derived from food averaged only 1,375 calories. To make good this discrepancy, therefore, Mr. Fletcher was compelled to draw upon his body material for 541 calories, and the data of the experiment from which the gain or loss of body material is determined show that he actually lost body material sufficient to

supply this amount of energy. Benedict, therefore, concludes that during the Yale experiment Fletcher's energy output could hardly have been less than 3,000 calories. The 1,300 calories representing the difference between the intake of energy as estimated in the food and the probable output during the excessive muscular exercise could be accounted for by the combustion of 150 grams, or about one-third of a pound of body fat. In the course of the short experiment of six or seven days there may have easily been a loss of one or two pounds of body fat, compensated by a gain of one or two pounds of water in the body, so that the body-weight would remain unchanged.

Fat and water constantly replace each other in the tissues. The rule for nitrogenous matter is that from 20 to 22 parts are found in association with 78 to 80 parts of water, but most organs contain more solid and less water than this, the explanation being that other solids with less affinity for water are in intimate union or stored up in them. Fat, *e.g.*, penetrates the interstices of the protoplasm as a dry, water-free mass, neither attracting nor repelling water, but as it increases the weight, the percentage of watery content is diminished. Lawes and Gilbert found that 80·8 per cent. of a fat sheep was made up of fat and water, the former amounting to 45·8 per cent. and the latter 35 per cent., whilst a lean sheep contained only 18·7 per cent. of fat and 53·7 per cent. of water. A man weighing 70 kilograms with 20 per cent. of fat might put on or lose 5 kilograms of fat without altering his composition otherwise; in the former case the percentage content of water would be lowered and in the latter raised. During inanition it is quite certain that the bone marrow replaces its loss of fat by withdrawing albuminous fluid from the tissues, and it is probable that when the fatty globules of the cells disappear and the fat cell collapses, small quantities of albuminous fluid pass into them, and make the tissues more watery.

With an excess of carbohydrates in the diet, the tendency of the body is to retain water in the tissues, whereas when fats largely predominate the tendency of the body is to lose water. Voit has demonstrated that dogs fed for a long time upon bread accumulate large quantities of water in their tissues, and in all probability the tissues of vegetarians are likely to become

richer in water than when a mixed diet is used. It is in any case significant that when carbohydrate is lost from the body, it is always in association with a greater quantity of water than normal. It is known that glycogen can increase to 19 per cent. in the liver and to 3.6 per cent. in the muscles, and if it be sodden with water in the same manner as nitrogenous matter, this would explain Voit's results.

In unpublished experiments upon other low-protein advocates, Benedict came to the conclusion that they took food of 40 per cent. more caloric value than they believed.

The 2,000 calories per day which Chittenden suggests was his own requirement for energy is a little higher than the estimate of the energy obtained from his diet and might be sufficient for an inactive man of little weight. But Benedict can hardly conceive that such a vigorous man as Professor Mendel could subsist on less than 2,800 calories per day, or nearly one-fifth more than Chittenden's estimate. In the same way the muscular activity of the soldiers with their drills and gymnasium work could not be satisfied with the scheduled 2,800 calories, and the explanation suggested for the athletes' low estimate is that on the days on which the diet was weighed and analysed less food was eaten than usual.

There is a general agreement that the energy requirement is that necessary for the voluntary and involuntary muscular activity, and the amount of food required is a function not so much "of the actual body-weight as of the mass of the active protoplasmic tissue muscle." Hence in most cases where the body-weight is excessive, less food would, during a short experiment, be required by drawing upon the fatty deposits of the body. But the energy of the food can only be lowered by lowering the energy output a corresponding amount, and this must necessarily mean diminished capacity for muscular activity to obviate a consistent withdrawal of the bodily tissues themselves.

He concludes, therefore, that although these experiments of Chittenden and others throw most valuable light upon the metabolism of proteins in the body, the evidence at present is not sufficient to warrant a permanent and material diminution of the amounts of protein now in vogue. He even asserts that this might be attended with serious disadvantages and probably

danger unless at the same time accompanied by a diminution of muscular activity.

In a paper published in the *British Medical Journal* (December, 1909) I expressed a doubt as to whether the average business man consumed anything like the amount of food or the allowance of protein suggested by the Voit standard, and I am pleased to be able to record an investigation made by Chittenden upon the daily protein consumption of 108 vigorous, healthy young men, with an average body-weight of 66·2 kilograms. The average daily amount of nitrogen eliminated in the urine was 12·87 grams or ·194 grams nitrogen per kilo of body-weight, as compared with ·228 gram of nitrogen per kilo of body-weight of the Voit standard. These men, selected at random, were found to be living by choice on a daily diet containing approximately 68 grams of protein, and yet there was nothing about their appearance, their physical or mental activity, or their state of health suggestive of lowered vitality or diminished efficiency. As Chittenden truly remarks, if natural instinct or primitive experience is of any value in the selection of a diet, "Why not grant as a possibility that these 108 persons were being guided by an instinct worthy of just as much credence as the instinct or appetite that prompts another group of men to consume daily twice the amount of protein food? Will not this kind of argument apply with equal force in either direction, and perhaps serve as an illustration of the questionable value of human instinct as a guide in meeting the physiological needs of the body?"

A RACIAL COMPARISON BY MAJOR McCAY

An instructive commentary upon Benedict's final contention is furnished by some figures, included in a valuable study of the metabolism of Bengalis, by Professor McCay, of the Medical College of Calcutta. He found that in mill work each 1,000 spindles in England required 4·2 workmen, in India 28; that each man in England was responsible for a weekly output of 767 yards of cloth, whereas in India his capacity was only 240 yards; although coal is much thicker, softer, and more easily cut in India, the output per man was only 80 tons, as compared with 287 tons in England. He attributed this entirely to the inferiority of the Bengali diet in protein

as compared with that of the English working man, because, although the majority of the natives of Bengal are vegetarians, the same relative infirmity is to be discovered in the physical development and capacity of those who do not affect a fleshless diet. Thus an examination was made of 38 students, whose diet included fish, mutton, and fowl, although their religion interdicted the use of beef. The daily excretion of urea was only 13 grams, as compared with 30 grams in the ordinary European, and the total daily excretion of nitrogen 5.9 grams to the 16 to 18 grams of the European. It is interesting to note that their blood-count showed no deterioration in cellular contents, there being 5,300,000 erythrocytes to 9,000 leucocytes, but only 79 per cent. hæmoglobin, although a similar investigation by Kellogg amongst actual vegetarians displayed 97 per cent. Similarly the blood-pressure of the vegetarian, with the Stanton modification of the Riva-Rocci apparatus, varied between 120 and 130 mm. Hg, whereas, in the Bengalis it was only 95 to 105. The weight of the latter only averaged 52 kilos as compared with 70 kilos of the European, and with the same height their average girth of chest was under 33 inches. Another important item in the research was the discovery that exactly one quarter of the total nitrogen of the food was excreted by the fæces, compared with 15 per cent. on a European vegetable diet, and this Professor McCay attributed to the use of dhal (pulse), which is responsible for most of the prevalent enteric disorders.

In order that no misunderstanding might exist on the subject, Professor McCay further examined the students of two colleges in Bengal, which included natives, Eurasians, and Anglo-Indians, living under identical conditions except diet. The diet of the Bengali students had a value of from 43 to 67 grams protein, 200 to 540 grams carbohydrate, 33 to 71 grams of fat, whilst that of the Eurasian and Anglo-Indian students contained 86 grams of protein, 376 grams carbohydrate, 55 grams of fat. At the end of the four years' school curriculum, whilst the Bengalis had increased about 2 inches in height, they had not increased their chest measurement, and their average gain in weight was only 2 pounds (42.8 per cent. having actually lost weight), whereas the Eurasians and Anglo-Indians had increased over

18 pounds in weight and an inch in chest measurement. The significant fact is noted that insurance companies rate the lives of Bengalis as inferior to Europeans, and demand a higher premium, so that they evidently look upon them as "poor" lives.

With the publication of his investigations of Bengal gaol dietaries, Major McCay has made a further important contribution to this subject, and upon a very careful comparative estimate of the different tribes of Lower Bengal he has no hesitation in concluding that the quantity of assimilable protein in a diet is the chief determining factor of the vigour, physical development, enterprise, and sociological status of a nation. In our survey of vegetarianism we have already dealt with his observations on the Bengali and Behari races respectively, the former living exclusively on rice, dhal, and vegetables, whilst the latter substitute a proportion of wheat for some of the rice ration. Both races, however, are vegetarian, less by desire than by force of circumstances, poverty being the impelling factor; yet the former metabolise $\cdot 15$ grams of nitrogen and the latter $\cdot 173$ grams of nitrogen per kilo of the body-weight daily, a decided increase on the $\cdot 12$ grams of nitrogen per kilo of the body-weight which Chittenden considers is all that is necessary for the protein requirements of the body. For reasons which he carefully details, Major McCay recommends that the above allowances be increased to a minimum of $\cdot 18$ gram of nitrogen per kilo of the body-weight each day, with a commensurate reduction of the carbohydrates. This would, as has previously been indicated, assure by reduction of bulk of food a higher percentage of protein absorption and so tend, by diminishing the amount of protein-content, to lessen putrefaction in the colon.

If instinct be of any real service in the selection of a diet, then in the case of these two races of people, its operation would demand an increase of their nitrogenous food, because there unquestionably existed such a desire for it that the promise of a small allowance of meat sufficed to put them on their very best behaviour, and whenever a chance occurred, as, *e.g.*, during the operation of cooking, the most careful supervision was essential to prevent its appropriation.

Major McCay considers that there is no doubt an increase in the supply of nitrogen adds to the productive capacity, and he instances the rapid development of the Japanese contemporaneously with a more generous protein ration, and remarks that in the Russo-Japanese War the commissariat department ensured an abundant supply of protein to the troops at the front.

In addition to the facts already enumerated in connection with the students, he has demonstrated from observations on the blood and urine of the Bengalis that the total nitrogen undergoing metabolism was only about one-third of that amongst Europeans, yet in spite of this fact a greater quantity of sulphates was excreted in the urine, indicating the presence of more intestinal putrefaction. The blood was decidedly impoverished, judging from the higher percentage of watery contents and its lower percentage of solids and protein. The hæmoglobin was reduced in quantity and the blood-pressure lower than the usual European level. Not more than 6 grams of nitrogen or, to be exact, 37·5 grams of protein were absorbed. A chronic state of nitrogen starvation was therefore present, compelling the body to extract its nutriment as far as possible from its own tissues; a state of affairs which easily accounted for the absence of subcutaneous fat, the loss of strength and vigour, and the complete lack of staying power.

The power of resisting disease was very much reduced, and this, contrary to Chittenden's statements, included the various types of renal disease, an occurrence remarkable in a country free from the ravages of scarlet fever, and amongst a people innocent of indulgence in alcoholic liquor. The extra third of an ounce of protein in the rations of the Behari was accompanied by a more generous physical development, and in particular a greater brightness of disposition and activity and liveliness of manner—their weight was greater by an average of 10 pounds per man than amongst the Bengalis, showing that the improvement in the rations was immediately reflected in an increase of weight.

The contrast between these two peoples of the plains was unmistakable and decided, but was immeasurably inferior in extent to that which was displayed by comparison with the hill tribes. Instead of lack of attention to the details of every-

day life and an air of introspection and disinterestedness in business, there was vivacity and alertness. The Beharis were a great advance upon the Bengalis, and all their conditions were alike except as regards the extra quantity of absorbable protein in the wheat. It is reasonable to conclude, therefore, that the defective nutrition was due entirely to the lack of protein. Kellogg has suggested that sexual excesses, bad climate, the actinic rays of the sun, the immature marriage-age, are more important factors than the diet; but these conditions likewise exist amongst tribes eating more protein, and have no deterrent effect upon an improvement of the physique. Besides which, the natives of Lower Bengal are entirely useless as soldiers, and it is found in India that those who join the army and are distinguished for manly qualities are never vegetarians, but usually large meat-eaters, *e.g.*, the Sikhs, the Rajputs, Jats, and Dogras. Experiments made on two sets of young monkeys in all respects like each other, except that the one set was fed on animal food, whilst the other set was fed on a vegetarian diet, showed that the former grew up much stronger and more ferocious than the latter.

Members of the hill tribes, instead of being lackadaisical, after the manner of the low-protein feeders of the plains, were alert, joyous, vivacious, talkative, and happy, while their children were playful and active, in decided contrast to the poor miserable, pot-bellied appearance of the progeny of the low-protein feeders. Yet the only difference between them consisted in the quantity of protein in their respective diets. The Nepalese Bhutias ate on an average 2 pounds of meat per day, and were big, strong fellows, with calves to their legs, and much in vogue as carriers. An examination of the diet lists of the hill tribes showed an amount of protein from 110 grams to 175 grams per man per day, and as much as 70 per cent. of this might be derived from animal sources, with an allowance of .35 gram of nitrogen per kilo of body-weight, nearly three times that recommended by Chittenden. Besides which they were quite free from dysentery and other intestinal ailments.

This is certainly a fairly strong indictment of the low-protein theory, and one which we cannot afford to disregard, because it does not possess the defects of even a nine months'

experiment, but all the force attaching to dietetic habits evolved in a natural manner, although limited by such restrictions as poverty and climate. May the explanation of some of the undoubted insufficiency of the Bengali diet as a satisfactory nutritive agent not reside, less in the quantity of protein absorbed than in the diseases engendered by the bulkiness of the food, diseases attended by the presence of toxins of one kind or another? Although the caloric value of the food was apparently much higher than in Chittenden's experiment, it was immensely reduced, not only by the more rapid evacuation of the bowel contents, but by the conversion of some of the food-stuffs themselves into toxins, which by absorption must have tended to reduce the vitality of the subjects. The instinctive desire for flesh foods may have been actuated by an earnest longing for a change, as a relief from the eternal monotony of rice, dhal, and vegetables.

Chittenden, in his observations on this admirable study of the nutrition of the Bengalis, contends that the results substantiate the view that the race can exist on a dietary of less than half the protein-content usually considered necessary. Its detrimental effect should not be ascribed to the low nitrogen-content, but to the character of the food, the unabsorbability of which was so great that 25.42 per cent. of the total nitrogen reappeared in the fæces. He considers it an excellent example of an ill-balanced ration, containing as it does a much greater abundance of carbohydrate and a much smaller quantity of fat than the Voit standard diet, and presenting an excellent breeding-ground for micro-organismal development and the consequent formation of toxic compounds. He does not attribute the improved physical condition after the substitution of wheat to the greater protein-content of the latter, but suggests that the wheat furnishes something which, added to the other constituents of the diet, increases the efficiency of the whole, as the action of lime-juice in scurvy. He declares that in the nutrition of the body there are many factors, aside from nitrogen and calories, which play a part in determining proper nutritive conditions. He refers to the immense improvement in the health of dogs, which were rapidly breaking down on a given vegetable diet, when a little meat or milk was substituted for a portion of

the vegetable matter, without in any way increasing the total amount of available nitrogen. And finally he maintains that under most conditions of life there should be no difficulty in maintaining a relatively low-nitrogen intake with an adequate fuel value by the use of food-stuffs which are reasonably digestible and available with freedom from excessive waste in the intestine.

Inferences.—Whilst it is important that during adolescence a full ration of protein should be consumed, it is quite clear that when full growth has been attained the smallest amount of food, and especially protein, that can be eaten, consistent with health and vigour, is the best. This will, of course, vary in accordance with the occupation and habits of the individual, and should diminish as age advances. I am quite convinced that the average business man does not eat nearly so much as is laid to his credit, although it is possible that he may err in eating a little too much animal food, which is practically forced upon him by his habit of taking too little exercise. It is pretty generally recognised that the less a man eats within reasonable limits, the more healthy is he likely to be; and Rabagliati, in an effort to differentiate between functional and organic disease, declares that disease almost always begins at some point in the digestive and bloodmaking and lymph-circulating processes, *i.e.*, that disease is a form of malnutrition. He further asserts that the particular phase of malnutrition which is commoner than all the rest put together, or at least the most common, is that which arises from excess of food.

A functional disease he characterises as one in which generally some blockage of the lymph-circulation exists in the capillary vessels lying between the veins and the arteries. When this advances a stage further, producing overgrowth of connective tissue, and an exudative process is manifest—a condition he calls *initis*, or congestion of the connective tissue—then organic disease is present. To determine the presence of this condition he applies pressure over the sternum, tibia, or mastoid, situations where nothing intervenes between the skin and the bone but connective tissue, and if any serious degree of pain be elicited, he concludes that excess of food is being consumed. Just how

far this test substantiates his claim I am unable to say, but in my own experience my well-fed patients usually evince less sign of pain than those who are below par. I can hardly think that the physics of the circulation, either of the blood or lymph, is likely to be much disturbed until actual arterial sclerotic or other manifest changes are produced.

The Urine in Low and High Protein Diets.—A comparison of the urine of those on a low-protein and those on a high-protein diet is of greater significance. Kellogg supplied such a table in his pamphlet already cited, and from this we learn that so far as one can judge the liver and kidneys in health are capable of dealing with all waste and toxic products of a high-protein ration, but just how far this is liable to interfere with their integrity it is impossible to infer.

	Low-protein Diet, without Meat.	High-protein Diet (Folin).
Quantity	1,000 cc.	1,430 cc.
Acidity in terms of H_2PO_4 gram ...	0.940	2.010
Total Nitrogen " "	6.440	16.000
Urea " "	11.650	29.800
Uric Acid " "	0.323	0.370
Ammonia " "	0.247	0.850
Creatinin " "	0.815	1.550
Chlorides " "	5.450	10.050
Phosphates " "	1.455	3.870
Total Sulphates " "	1.071	3.140
Ethereal Sulphates " "	0.116	0.220
Indican (Fehling's Solution = 100) " "	5.600	77.000

Whilst at Yale in the spring of 1909 I had ample opportunities for interviewing those colleagues of Professor Chittenden who had been collaborating with him in his important work, and without any exception they supported his contention that a low-protein diet was ample in its supply of nutriment and satisfying in its potentiality for work.

His able coadjutor, Professor Mendel, who occupies the chair of Biological Chemistry, considered that the great experiment had at least established the protein minimum requirements of the body. As he personally was rather a

heartly eater, the only way he could adopt the low-protein diet was by becoming a vegetarian, and this he did for the full 225 days. After the experiment he returned to a mixed diet with less protein than formerly, because he believes that this is the one best fitted to subserve the proper nutritive requirements of the body.

Dr. W. G. Anderson informed me that on account of increasing fatigue and loss of endurance he dropped his high-protein diet at the time of the great experiment and adopted a low-protein one, with the result that now he is in the best of health and condition. His chest capacity had increased by 2 inches, and his muscles, which I had the privilege of feeling, were as hard as iron bands.

Professor Irving Fisher stated that on account of a serious breakdown in health he was advised to adopt a system of overfeeding. Although by this means he was able to rout the disease which threatened to overwhelm him, he experienced a great lack of energy, and had no capacity for endurance. Since, however, he had adopted the low-protein mixed diet, his production of energy and capacity for endurance left nothing to be desired. He certainly looked the picture of health.

Having thus considered the evidence for and against a reduction of the protein in the standard diet, however damaging the arguments against such a proposition may appear to be, we are entitled to hold that convincing testimony has been rendered in favour of moderation. It is also pretty clear that the protein minimum is much lower than had previously been established, and sufficient warrant for cautious experimenting with minimal protein rations has been presented. During a period of compulsory sedentary employment, it is more than probable that much benefit would be obtained by diminishing the quantity of all the alimentary principles, but when the mind is free from harassing intellectual operations and physical activity is renewed, a demand for a temporary increase in the protein ration is not only normal but inevitable. The risk is that on the cessation of the muscular exertion the augmented diet may be persisted in, for in such circumstances it is indubitable that the organs of excretion are in danger of being overtaxed. The influence

of the weather is likewise of great importance, a large ingestion of protein in the summer-time being accompanied by an increase in the heat production and a corresponding increase in the excretion of perspiration. Meat is therefore better avoided in hot weather, although during the winter-time it is valuable as producing an extra amount of heat.

CHAPTER V

PURIN-FREE OR URIC-ACID-FREE DIET IN THEORY AND PRACTICE

THE best known modern theory of diet is the purin-free, or, as its author, Dr. Alexander Haig, with a certain lack of scientific precision entitles it, the uric-acid-free diet theory. It is quite fair at the very outset of our inquiry to seek for an accurate definition of the term "purin-free diet," for it is pretty apparent that amongst the foods permitted by its advocates many are included, *e.g.*, milk and its derivatives, which are by no means devoid of purins. It should be noted that the term "purin bases" applies to hypo-xanthin, xanthin, adenin and guanin, the four precursors of uric acid, while the term "purin bodies" includes these four substances with the addition of uric acid.

It must be clearly understood, therefore, that an absolutely purin-free diet is practically unattainable. Probably this is a very fortunate circumstance, for it is indubitable that the animal cell requires both nucleic acid and purin bases for the purpose of building up nucleo-proteins, which are absolutely essential for enabling the body to carry on its business, and can, indeed, be separated from almost every one of its organs. It is possible, however, that the body may be able to manufacture purin bases for itself, as we know this is effected in incubating eggs. Despite this fact, we are quite justified in saying that the purin bases and other components of nucleic acid to be found in so-called purin-free articles of diet are used in the construction of the body cells and especially of the nuclei.

It is therefore impossible to separate with precision the

urinary uric acid which is derived from the food from that which comes entirely from cell metabolism, because manifestly some of the endogenous uric acid may owe its origin at no remote date to the purin bases of milk products. For all practical purposes, however, it may be asserted that a purin-free diet is one which is capable of maintaining the output of uric acid at the lowest level possible for the individual, and this is, presumably, almost entirely of endogenous origin.

The advantages to be derived from the adoption of such a diet are sometimes so notable that there is a tendency on the part of an enthusiast to look upon it as a panacea for "all the ills that flesh is heir to." In recent times there has been a surprising accumulation of favourable opinions in support of it, and amongst a certain section of the profession it has been taken for granted that the objections, which have been exposed time and time again, no longer hold any weight, and that the uric-acid theory so-called has been proved to a demonstration. From the theoretical point of view, the arguments in its favour are so plausible and so difficult to refute, that one is apt lightly to advocate its adoption, without considering the consequences. For some years now I have been much attracted by its possibilities in the treatment of disease, and in selected cases, where the ordinary therapeutic methods have failed, I have had no hesitation in encouraging patients to give it a thorough trial.

It is astonishing what a fascination such a theory has for the young and enthusiastic physician in the first flush of his disappointment with both old, well-worn remedies and new much-vaunted specifics. On the face of it, the whole thing seems so absurdly simple that it does not need any elaborate demonstration to prove its truth. The body of your ailing patient is a more or less intricate filter, into which, for purposes of nutrition, have been poured certain solutions of nutriment containing certain poisons which are not completely excreted, and hence accumulate therein, producing well-defined acute or chronic diseases, according to the temperament of the patient. To eliminate the disease, all that seems necessary is to expunge the poison from the food, and, where this cannot be done, to select foods which contain no poison,

and you go forward with the simple, and at first not easily shaken, faith that disease in such circumstances is really an impossibility.

The practice of the purin-free diet may have existed long before Dr. Haig's time, but most certainly the theory—and, coeval with this, its inclusion as a branch of dietotherapy of decided value—originated with Dr. Haig. The description of its evolution in his fertile brain is carefully detailed in his now well-known treatise on the subject—a treatise which, from the empirical point of view, may be looked upon as one of the first efforts to put the practice of dietetics on a scientific basis. It reads like a romance, and would bear complete transcription; but I must content myself with giving the briefest résumé of the facts, in order that we may understand the theory and demonstrate some of its fallacies.

History of the Theory.—It is an unquestionable fact that purins are poisons to many people, as they most certainly are to Dr. Haig. They are mainly excreted by the kidneys as uric acid, and this is the keystone of the superstructure he rears on the fact of his intolerance for purins. As a student he was a martyr to headache, and found that by diminishing the quantity of flesh foods he produced an amelioration of this troublesome ailment. He noted that the headaches were always accompanied by a large excretion of uric acid in the urine, and that when he was able to reduce the amount of this excretion he could assuage the headache. This he effected at first by administering a dose of mineral acid, and coincident with the relief, he often detected pricking and shooting pains in his joints and elsewhere. At the same time he discovered that the administration of an alkali increased the uric acid in the urine and induced the return of the headache. He thus argued that uric acid was directly or indirectly the cause of the headache and other allied conditions, as well as the most important factor in rheumatism and gout. Thus at the very outset, on what must be confessed as rather insufficient data, he enunciated the doctrine that there were two great classes of uric-acid diseases—those which, like headache, were due to its excess in the blood and therefore in the urine, and those, like rheumatism, due to its excess in the

joints and fibrous tissues and its diminution in the blood and urine.

He likewise noted that the headache was associated with high blood-pressure, and this suggested that uric acid might in some way exercise some controlling influence over the circulation. Reflecting on the well-known facts of Raynaud's disease, and watching the fluctuations in his own capillary circulation, he concluded that uric acid controlled the capillary circulation of the body, and that the greater the quantity of uric acid there is in the blood, the more sluggish is the capillary circulation, whereas the less uric acid there is in the blood, the freer and more responsive is the capillary circulation. The uric acid excreted in the urine, he considered, was an index both to the amount of uric acid in the blood and to the rate of the capillary circulation. He therefore inferred that the blood in Bright's disease, in cerebral hæmorrhage, and whilst it was under the influence of alkalis and salicylates, would always contain an excess of uric acid, whereas in fever, or after the administration of acids, it would always display a scanty content of uric acid. He professes to demonstrate this by mixing a little of the blood with chloride of ammonium solution, when the uric acid is precipitated in the form of granules, and this, taken in relation to the number of erythrocytes, gives, he asserts, an absolutely correct index of the amount of uric acid in the blood. This, however, he considers is a work of supererogation, as the same fact could be substantiated by what he calls the capillary reflux—*i.e.*, the time in half-seconds taken for the return of the blood to the capillaries from which it had been ejected by the pressure of the finger. It is quite fair to observe, at this point, that although Garrod has established the fact that the blood of gouty persons contains uric acid, no one, apart from the above testimony, has been able to find it in normal blood. The ammonium chloride reaction and the capillary reflux must, therefore, be open to an interpretation other than that suggested by Dr. Haig, as these phenomena can apparently be elicited in the blood and circulation of normal people.

Recognising that uric acid was a normal product of tissue katabolism, he postulated that the particular quantity due to this cause could always be excreted without harm to the

organism, but the inclusion of any further quantity in the food was at least liable to be accompanied by its excessive presence in the blood or tissues. He even goes further now, and asserts positively that this additional food purin always damages the body in some way, and in particular in a colloidal form blocks the capillaries, obstructs the flow of blood in the veins, and so, when the heart is strong, induces a rise of blood-pressure. In people whose blood is fairly free from uric acid such a small quantity as 3 grains of uric acid introduced into the blood will produce to a slight extent this condition, which he calls collæmia, whereas when a large dose, say 30 grains, is swallowed, quite a different result is brought about. This quantity is too great to be dissolved by the blood, and so, carried to the liver, it is retained there, the blood and urine are cleared, the capillary reflux quickened, the metabolism is stimulated, and a feeling of strength and power results, as if a tonic had been taken. These statements hardly coincide with the well-known fact that the administration of uric acid by the mouth is quickly followed by its excretion, chiefly as urea, although a distinct proportion of it is eliminated unchanged in the urine.

This, in his opinion, is the explanation of the stimulating effects of meat soups, beef-teas, gravies, and acids, which drive the uric acid out of the blood into the liver and other organs. This stimulating effect is only temporary, and is quickly followed by depression, with a slow capillary reflux, due to the uric acid stored up in the liver and tissues being dissolved out. The blood becomes flooded with uric acid in a colloid state, and there is an excessive excretion of the uric acid in the urine. By eschewing foods containing purins, it is possible to increase the solvent power of the blood for uric acid, and, as it is quickly excreted, it is never stored up in the liver or other tissues. The result is a fall in the blood-pressure, a quicker capillary reflux, and what he calls an increased blood decimal.

He states that uric acid is always found in the body in a definite quantity in relation to urea, about 1 to 35, so that an excretion of 420 grains of urea should be accompanied by 12 grains of uric acid. If an individual with such quantities were to increase his ingestion of purins, then his blood would

not be capable of dissolving all the uric acid formed, and as it could not be excreted, it would be stored up in the tissues. The blood can dissolve uric acid in proportion to its alkalinity; but being always alkaline it can always dissolve a certain quantity. Its solvent power for uric acid can be increased by taking substances which increase its alkalinity, and diminished by substances which reduce its alkalinity, or which form directly an insoluble compound with uric acid. There is, he declares, a continual interchange of uric acid between the blood and the tissues. In the morning, the blood is a good solvent of uric acid, and takes it up from stores deposited in the body; in the evening it is a bad solvent, and gives it up to the tissues. Hence headache and irritability are common in the morning, while high spirits prevail in the evening. So also arthritis is worst then and in the cold season of the year. Uric acid in the tissues produces irritation; but for this purpose it must be in solution, as solid deposits of biurate of soda cause no discomfort.

Uric acid, or its equivalent, is contained in fish, flesh, fowl, and eggs which are not quite fresh, to the extent of 6 grains to the pound. Xanthins in peas, beans, lentils, peanuts, asparagus, and mushrooms, may reach 16 grains per pound, and as much as 175 grains are contained in a pound of tea, half this quantity in coffee, and one-third of the amount in cocoa.

He affirms that as uric acid controls the circulation, it likewise exerts its sway over the metabolism. Oxygen not being able to reach the tissues from the blood during collæmia, the albumin of the tissues is not properly burned up into urea, acids, &c., and so is excreted unchanged by the kidneys. Subjects of the collæmic group of diseases may be recognised by the puffy condition of the skin and lower eyelids, in some cases amounting to œdema. The eyes are likewise unduly prominent, a sign of high blood-pressure, notably so in exophthalmic goitre. In such cases the blood-pressure may be as high as 180 mm. Hg, and so long as the heart is strong there is no danger of the rupture of blood-vessels. All sorts of diseases are therefore likely to arise—dyspepsia, liver disease and diabetes, albuminuria, depression, fatigue, neurasthenia, &c., and Dr. Haig goes the length of saying

that by examining the capillary reflux without seeing the face at all he could indicate what the physical, mental, and moral nature are likely to be. The precipitation group of diseases includes gout, rheumatism, and all local inflammations of fibrous tissues, such as bronchitis, colitis, neuritis, appendicitis, &c.

It is quite impossible to do justice to the theory in this fragmentary account of it, and despite the blemishes of the treatise, I would counsel every medical man to study it carefully. It is a perfect mine of valuable clinical facts, and is of special interest to the man who has forgotten much of his pathology, because it provides him with a form of clinical pathology which is particularly useful in therapeutics.

Criticisms of the Theory.—The obvious remedy for the conditions which have been described seems to be to exclude all purins and xanthins from the diet. When disease has arisen from a prolonged course of the ingestion of the poison, all that is necessary is to refer it to one of the two groups and administer solvents or precipitants of uric acid respectively. The whole thing appears to be simplicity itself, and one is apt to become enthusiastic to a degree in the application of the rule. Even when, after much patient research, you prove without a shadow of a doubt that the bulk of the purins and xanthins ingested are as a rule easily excreted within forty-eight hours, you do not lose faith, and you look round upon the countless examples of healthy men and women who have lived to a good old age, and have triumphed over all the dangers of the foods which Haig places upon his expurgatorial list, as having become in some unaccountable way possessed of the true elixir vitæ. After a few years' careful observation, however, you are not quite so sanguine as to the infallibility of the cure-all, and when you begin to investigate the matter carefully you find that the objections to the theory may be grouped under three different heads.

(1) OBJECTIONS FROM THE CHEMICAL POINT OF VIEW

Dr. Haig depends for his estimation of uric acid in the urine on the Haycraft process, which he considers rapid and very constant in its results. Even although it may be all he claims

for it from a clinical point of view, it is evidently not accurate enough to satisfy the requirements of scientific research, and it is significant that every physiological chemist of repute has discarded it long ago as unreliable. If I may speak from my own experience in a fairly long research on the subject, I should say that it over-estimates the quantity of uric acid. In any case, I submitted samples of the same urine from which I had been working to the most competent observers—one using Haycraft's process, the other the Ludwig-Salkowski method—whose names I am not at liberty to publish, with the most discordant and absolutely irreconcilable results.

The most exhaustive and trustworthy research on the urine has been made by Professor Folin, of Harvard, and he has formulated a series of laws governing its chemical composition, which are of such general applicability that they are now accepted by physiological chemists in the light of principles. The three leading points in Dr. Haig's theory are:—

(1) That the relation of uric acid to urea is constant, viz., 1 to 35 or thereabouts.

(2) That the quantity of water in the urine varies from hour to hour and from day to day inversely as the uric acid excreted along with it.

(3) That the acidity of the urine varies inversely with the excretion of the uric acid, and directly with the excretion of urea, being low when the uric acid is high, and high when the urea is low.

Folin and the Chemistry of the Urine

In each of these conclusions he is at variance with Professor Folin, who finds that:—

1. "When the total amount of protein metabolism is greatly reduced the absolute quantity of uric acid is diminished, but not nearly in proportion to the diminution in the total nitrogen, and the percentage of the uric acid nitrogen in terms of the total nitrogen is therefore much increased."

As regards the urea, he finds that it is "the only nitrogenous substance which suffers a relative as well as an absolute diminution in the total protein metabolism." The

evident amount of uric acid will therefore increase out of proportion to urea when the quantity of protein food is diminished, and diminish when the quantity of protein food is increased. The relation, therefore, cannot be constant. It is a mistake to think that in the absence of food the hourly excretion of endogenous uric acid will be constant, for evidence is accumulating to show that under exceptional circumstances, such as starvation or a low nitrogenous diet, the absolute quantity of endogenous uric acid eliminated may be diminished, although in Chittenden's long experiment the output of uric acid was very little affected. It is also notable that the ingestion of a purin-free meal increases the uric acid output during the hours immediately following the ingestion of the food above the quantity obtained during abstinence. When in similar circumstances purin-free egg-proteins are administered a still greater quantity of uric acid is eliminated.

Haig's accurate observation that uric acid is excreted chiefly in the morning hours, when the output of urea is moderately low, and is diminished in the evening hours, when urea appears in greater quantity, is in practical agreement with the results of an investigation made into the subject by Leathes and Cathcart, who are, however, unable to give assent to the assumption that the excretion is controlled by the acidity of the urine. According to Leathes, the total nitrogen-content of the urine is greater during the night than during the day, confirming the belief that the renal activity is at its maximum during the night. The uric acid excretion, on the other hand, is greatest in the morning, between 10 a.m. and 1 p.m., steadily declining until it reaches its minimum in the earlier part of the night, an augmentation being observed at the usual waking hour of 7 a.m., and gradually increasing thereafter. He is chary of offering any explanation of these facts, but insists that they are occasioned by diminished functional activity of some organ other than the kidney.

It is fair to add that Leathes' observations were made on subjects who were fed every three hours during the day on purin-free meals, at each of which the same volume of fluid was consumed, with the express object of eliminating irregularity in excretion. This variation from ordinary conditions

doubtless accounts for some otherwise unexplained differences, and with some diffidence I advance the following suggestion, which renders it unnecessary to appeal to the reaction of the urine. During the activities of the day, when the muscular metabolism is at its height, the skin and lungs are called upon to make greater excretory efforts than the kidneys, and hence a greater volume of blood passes through the former, whereas during the muscular repose of the night the kidneys are in a better position for obtaining a larger share of blood, and thus exercising their function as the chief excretory organs of nitrogenous waste. Few people eat much after 7 p.m. or between that hour and 8 a.m., and as a rule what they do eat, even in the morning, contains a minimum of protein. Hence most of the urea is expelled before the time for getting up, and as the excretion of uric acid is now at its height, its proportion in relation to urea is therefore markedly increased in the morning hours. Urea is manufactured in the body independently of muscular action, the quantity being controlled entirely by the supply of protein food, whereas uric acid and creatinin are in some way associated with muscular contraction, and their excretion begins to increase the moment the organism wakes to active movement. Burian and Schur consider that endogenous purins formed in the tissues are there oxidised to uric acid, some of which is destroyed by the liver, and some of which is excreted as such by the kidneys. They believe this is proved by the effects of diuretics, which increase the elimination of uric acid by increasing the flow of blood to the kidney, and do this without affecting the other nitrogenous constituents of the urine. They further believe that half the total quantity of the blood passes through the kidneys.

So far as I can determine I am unable to satisfy myself that any constant relation, other than that mentioned, exists between the excretion of uric acid and urea. By testing samples of twenty-four hours' urine from day to day, it is quite possible to corroborate two of Dr. Haig's statements, however: (1) that exposure to cold causes a temporary diminution in the excretion of uric acid—which I attributed to an increased metabolism; (2) that salicylates cause a distinct and decided increase in the excretion of uric acid, even on a purin-free

diet. This has been explained in various ways, notably by Walker Hall and Kellogg, the latter of whom asserts that, like all antiseptics, salicylates act as irritants, primarily on the intestinal mucous membrane, hence producing indigestion and absorption of imperfectly digested peptones, and secondarily on the tissue cells, reducing metabolic activity. Haig declares that they form a soluble compound with uric acid (salicyluric acid) and excrete stored-up or retained uric acid. This, however, has not been corroborated. A much more likely hypothesis is that, like alcohol, they inhibit the action of the uricolytic enzyme and so prevent the destruction or metabolism of uric acid. Minkowski admits the beneficial influence of the salicylates on gout and allied ailments, but attributes it to their analgesic properties and their power to promote perspiration.

2. According to Folin, "The volume of urine eliminated depends directly upon the amount of water consumed, and in no way has any constant relation to the loss of nitrogen. It is, indeed, largely a personal peculiarity, and to a great extent varies inversely in proportion to the amount given off by the skin." I have made frequent observation in my own case in the morning hours, when proportionately large quantities of uric acid are being expelled by the kidneys, and when, according to Haig, there should be a difficulty in passing urinary water. I have invariably found that a pint or a pint and a half of hot water swallowed at 6 a.m. is all excreted before 8 a.m., and this would not be the case if colloid uric acid blocked the capillaries of the kidneys.

3. There is room for considerable difference of opinion regarding the nature and causation of the acidity of the urine. The acid reaction is dependent on the acid products of metabolism formed by the combustion of such neutral substances as albumin and lecithin, the contained sulphur giving rise to sulphates and the phosphorus to phosphoric acid. Many other organic acids, such as oxalic acid, uric and hippuric acids, with aromatic oxy-acids are found in normal conditions, while in pathological conditions oxy-butyric and diacetic acids are also found. In any case the acidity is never due to free acid, but always to acid salts, the most common of which is acid sodium phosphate, and it unques-

tionably varies even in normal circumstances, because the organism is possessed of a regulating mechanism for keeping the acidity within certain limits.

The most important modifying factors are diet and digestion. The former is exemplified in herbivorous animals and vegetarians, where the reaction is alkaline because of the excess of alkaline salts of such organic acids as tartaric, citric, and malic, contained in the food. These are oxidised into carbonates, which determine the alkaline reaction. That this is due to the diet is manifest, because during starvation, where herbivorous animals are living on their own tissues, the reaction of the urine becomes acid. In carnivorous animals likewise, where the urine is normally acid, feeding on vegetables causes the urine to become neutral or alkaline.

During active digestion, on account of the formation of free acid in the stomach, the bases with which it has been combined are liberated in the blood, and passing into the urine, diminish its acidity, or mayhap render it alkaline, thus producing the alkaline tide, while an acid tide is to be noted during fasting conditions, *e.g.*, several hours before breakfast. This is rather inconsistent with the dictum that the acidity of the urine varies inversely with the excretion of uric acid, because it is just in the early hours that Haig asserts the greatest quantity of uric acid is excreted.

It is, however, a moot point whether uric acid is ever excreted as such. We must remember the great insolubility of uric acid, and its tendency to form supersaturated solutions, as well as the much greater solubility of the acid urate of sodium. Camerer's observations in connection with this salt are of great interest. He mixed a saturated solution of acid urate of sodium, which showed an alkaline reaction, with a solution of acid phosphate of sodium. This solution of mixed salts was perfectly clear at 37° C. and displayed an acid reaction with litmus. By cooling the mixture the reaction became alkaline and uric acid was deposited, the acid phosphate of sodium (NaH_2PO_4) having attracted the soda from the urate salt, forming disodium phosphate (Na_2HPO_4), and thus setting free the uric acid in a crystalline form. Heating the solution again restores the original acid mixture of salts. Now in the urine a considerable quantity of the uric acid is

present as the mono-sodium salt, but not all of it, because all the uric acid cannot be precipitated by an addition of acid. Even after acidification a part of the uric acid remains in solution, and it is worth remembering that urea is a good solvent for uric acid.

It is obvious that the term "acidity" both as regards the urine and the blood, must be regarded as purely relative, depending largely on the indicator used. Acid sodium carbonate, *e.g.*, is chemically an acid salt, yet it turns red litmus blue, is neutral to phenolphthalein and alkaline to methyl-orange. Carbon dioxide again exists under tension in simple solution

in the blood, and this it could not do unless the plasma acted as an acid. We can hardly be surprised, therefore, that regarding the acidity of the urine Folin makes a decided departure from the views usually held. He considers that the current belief that the acidity of the urine is regulated by variations in the relative proportions of the two forms of "acid phosphates" is erroneous. In common with most observers, he admits that there is no really good method for determining the degree of acidity of the urine, and in his interesting article on the subject makes many suggestions of decided value. Haig is so far correct regarding the acidity being proportional to the amount of urea, in that the greater the amount of protein food that is taken the greater will be the urea and the acidity, but the same remark obviously applies to the uric acid. It is a fact, however, that where a sufficient amount of alkali is present in the blood an alkali-protein appears to inhibit the uricolytic enzyme.

2. OBJECTIONS FROM THE CLINICAL POINT OF VIEW

It is probably not in the nature of things that one should expect such brilliant therapeutical results by the use of a purin-free diet as are obtained by Dr. Haig. For it is evident he is obsessed by the doctrine that uric acid is the causative factor in many, nay, most diseases, and proclaims this gospel with such emphasis that he cannot fail to arouse the enthusiasm of the chronic invalid, especially when, as is usual, other methods of treatment have failed to produce any material benefit. One, however, is not long in determining that many

forms of disease—often refractory in the ordinary course—are unquestionably greatly ameliorated by adopting a diet containing a minimum of purins; but careful reflection and calm dispassionate consideration of the cases leave one in much dubiety as to whether the benefit must be ascribed to the restriction of the purins and not to some other factor.

The only way to elicit the curative or preventive properties of any diet is to test it in suitable cases. On account of an irresistible power of attraction, my therapy was for many years strongly tinged with the purin-free theory, and I made a point of treating every chronic case which failed to respond to recognised therapeutical method by the imposition of a purin-free diet, and during this quest I was able to form very definite views as to its limitations. I have tested the system in the following groups of cases:—

Group I.

Headaches.—This group comprises headaches of a periodical nature, sometimes accompanied by sickness, at other times not, but always of the character so generally ascribed to the condition known as uric-acidæmia. All these cases occurred in ladies who refused to adopt a rigorous purin-free diet, but as a compromise agreed to give up tea, coffee, and cocoa. In the six cases I had noted the results were remarkable, as after a preliminary exacerbation of the headache it disappeared never to return.

I am of opinion that the great majority of such headaches in women are due to caffen poisoning, and for a long time are kept at bay by an extra dose of the poison, so that it becomes quite a common thing for the sufferer to fly to another cup of tea in order to obtain relief, with disastrous results in the long run. Tea, coffee, and cocoa are nerve poisons, cardiac poisons, and cerebral excitants, and the headache is sufficiently explained by the toxic factor, without having recourse to the statement that xanthins are analogous to purins, and hence converted into uric acid, or one of its congeners, and as such accumulate in the body. Whenever the dose of the poison is reduced to the amount the body can tolerate, the bad effects cease. Probably the temporary relief obtained by a cup of tea is due to the fact that caffen quickly

acts as a diuretic, and leads to an increased excretion of the nitrogenous elements, especially of urea, and the fatigue products generally. This is possible only with moderate doses, because it has been experimentally demonstrated that the greater the quantity of caffen absorbed, the less in proportion is it metabolised, and, as much of it is retained, the total urinary purin is proportionately diminished. This cumulative action sufficiently explains the toxic effects of large quantities of tea and coffee. However close may be the association between xanthin, hypoxanthin and uric acid, there is no evidence to support the belief that methyl-xanthins, the urinary degradation products of caffen, theobromin, and theophyllin, can be converted into uric acid, or exercise similar functions. As a matter of fact, the methylated purins found in tea, coffee, and cocoa are, when ingested, not oxidised to uric acid, but appear in the urine as purin bases.

In this connection my own personal experience is of interest. For quite half a dozen years I had, on an average, three attacks of migraine each week, which never failed to be relieved by small doses of citrate of caffen, antipyrin, salicylate of soda, and bromide of potassium. In my extremity I have tried all these remedies singly, in pairs, and even three together, without avail. It was absolutely essential to combine the whole four to effect a cure, and even although diuresis was effected by other remedies, the severity of the headache was never mitigated. In common with Dr. Haig I ascribed the attacks to uric acid, but quite ten years ago a pair of cylindrical glasses effectively banished my torture by correcting an infinitesimal degree of astigmatism.

Group II.

Epilepsy.—In this malady, in my experience, a purin-free dietary offers the best chance of a cure, and two of my cases after years of suffering have quite got rid of their attacks. In neither case, however, was the diet absolutely purin-free, although the rules laid down by Haig otherwise were carefully followed—viz., (1) that a minimum of fluid be taken, (2) that the bowels be kept open extremely well; and I added a third instruction, to avoid all salt in the food, replacing it in the

bread used by a small quantity of sodium bromide. A third case has now been under treatment for nine years without having had a single attack, as compared with one every three months before that; the only purin-containing food allowed is 6 oz. of some kind of animal food once daily. This case, as well as the three I am about to mention, has had in addition each day, for the first two years of the treatment, 10 minims of tincture of digitalis and 20 grains of sodium bromide. These three cases, on a limited purin-free diet, had not a single bad symptom during their course of treatment, differing markedly from the next three on a purin-free diet.

These three cases, the details of which it is quite unnecessary to publish, unquestionably for a time derived considerable benefit from the adoption of a rigorous purin-free diet, and just at first their epileptic attacks were distinctly reduced in number; but after a variable interval—nine months in one, eighteen months in another, three years in a third—each one was attacked with indications of severe physical debility: muscular rheumatism in one, nasal catarrh, indigestion and amenorrhœa in another, with anæmia and great physical exhaustion in all three, and coincident with this breakdown in health in two of them, the attacks of epilepsy recurred as badly as ever. The third case has had no further attacks of epilepsy, but remains in her exhausted condition, although she considers the freedom from epilepsy cheaply purchased by the substitution of her other maladies.

In common with all my other patients on a purin-free diet, these three felt the cold severely. Two of them, however, are so convinced of the value of the diet in their malady, that they insist on persevering with it for a longer period, and as I am quite certain of at least the temporary value of such a mode of dieting in most chronic maladies, I have encouraged them in this desire, although from experience I expect a recurrence of their trouble in perhaps a less aggravated form. This great reluctance to give up a fleshless diet after it has been persevered in for months or years is a special feature in many cases. Some of them seem to think there is a special virtue in carrying out such a regimen, and although they do not quite look upon themselves as martyrs in a good cause, they have a sense of importance which is almost religious in its

fervour, and which is much intensified when they lose all taste for animal food. This the vegetarian takes to be an absolutely certain proof that his is the only natural diet, forgetting that it is quite possible to find people who have in similar manner lost all taste for fruits and nuts.

It is a notable fact that after having been on a purin-free diet for a lengthened period, a return to mixed diet is often followed by bad results, due to the loss of digestive power from disuse, and other causes, but not necessarily due to the purins. Meat juices and gravies, probably owing to the purins they contain, are strong peptogenic agents, being the strongest stimulants to the digestive powers which we know, but, like all stimulants, in excessive quantities they are apt to exhaust the functions to which in small quantities they are valuable adjuvants. Each food has its own special peptogen or digestive stimulant, which acts best when the stomach is for a short time accustomed to its stimulus, but when deprived of it for some time, it does not at once respond to its peptogenic properties. This I believe to be the explanation of the bad results of resuming a mixed diet after a temporary deprivation.

I am sure that quantity of food has much to do with the attacks of epilepsy, as it is a common thing for such patients to remark that an increase in weight is the prelude to an attack, and they are almost invariably correct. The only certain fact we know in the pathology of epilepsy is the instability and proneness of the cortical cells to discharge their energy; and increased blood supply is a highly probable factor in this irregular discharge of nervous energy. Purins in the blood may act as irritants, but it is much more likely that they stimulate the appetite, especially for nitrogenous foods, which are the chief source of nerve energy, and in this way precipitate an attack. Total deprivation of purins seems so to disorder the digestions of those once accustomed to them that toxæmia is produced, and this of itself is apt to set up convulsions. Where, however, a good digestion, not spoiled by years of bromide administration, exists, a purin-free diet, especially in recent cases, will be found most valuable, and even in confirmed cases of the same type will diminish the frequency or severity of the attacks. In the average case,

however, a diet without free purins, but only those contained in a small quantity of the accustomed animal food, will be found more suitable.

Group III.

Asthma.—I have put a considerable number of cases on a purin-free diet, with the almost constant result of a temporary—sometimes prolonged—improvement, and after a few months a more or less severe relapse. All of the cases manifested a distinct and decided improvement for a few weeks or months after the adoption of the diet, but, with one exception, after a time—in one case as long as two years—they began to lose strength and weight, develop anæmia or rheumatism, or some other ailment indicating a lowered vitality. The exception was a young lady aged twenty, who had suffered from asthma for many years, and who for eighteen months after adopting a purin-free diet had complete freedom. Then the attacks recurred, although less frequently, and, thinking she could be no worse, she added a little animal food to her dietary. This, however, made the attacks much worse, and she is now again on a purin-free diet with comparative freedom from asthma. It is quite possible that the youth of the lady is in her favour, and for this reason she may find salvation in a purin-free diet.

It will thus be seen that my experience of the purin-free diet in asthma is very similar to that in epilepsy, and that an initial improvement was almost invariably obtained, but after a fairly definite period a recrudescence took place. I can hardly resist the conclusion that the explanation of the improvement from the diet is somewhat on a par with that due to a change of climate, and probably both are brought about by metabolic stimulation. When the metabolism flags, toxic products reappear and lead to a return of the malady. The cause of asthma is probably varied, but is closely bound up with the pneumogastric nerve, and it is hardly to be wondered that change of air and change of diet should both bring about temporary amelioration of the condition.

Group IV.

Neurasthenia.—I have notes of two cases of this condition. In one, although the diet evidently suited her admirably,

her neurasthenic condition was no whit better after eighteen months, whilst the other, and a third case that was reported to me, broke down at the end of nine months, and both were compelled to indulge in the luxury of a rest-cure before a return to health was assured.

Group V.

Variable.—Of isolated cases the most remarkable are the following:—

1. A young lady who for nine months had attacks of cyclic hæmatemesis. Every fifteen or sixteen days a violent vomiting of venous blood occurred, upon which no amount of medication or attention to the laws laid down by three eminent physicians made the slightest impression. As a last resource I persuaded her to try the purin-free diet, the result being a brilliant cure. At the end of a year, however, she was thinner, weaker, anæmic, and tired of life, and had the greatest difficulty in compelling herself to eat anything at all. The addition of 6 or 7 ounces of animal food to her diet soon caused an improvement in her health, but with increased appetite and indulgence the attacks returned, with less frequency. She is now quite well so long as she adheres to the smallest possible amount of a mixed diet.

2. A lady who suffered from some peculiar form of ulcerative skin disease from childhood. All sorts of medical and spa treatments were tried without effect, and when she started the purin-free diet she had a large number of active ulcerative patches, besides being covered with the scars of old ones. In five months after adopting the diet she was quite free from active disease of the skin, and only regretted that there was no chance of eradicating the scars. At the end of twenty-two months—that is, seventeen months of freedom—another ulcerative patch appeared, and since then a good many more have broken out. She, however, adheres to the diet, because she has come to like it.

3. A lady, aged thirty-two, who had muscular pains and slight swellings in the joints occasionally. At the end of eighteen months on the diet she could report little betterment as to these discomforts, but had lost weight, become anæmic, and was quite tired of life. Nine weeks after adding a moderate

amount of animal food she had recovered her usual strength and weight.

Two patients whilst on the diet developed glycosuria, which soon disappeared on cutting down the starchy food.

Another case is remarkable, not only from the fact that he is one of the few who have persevered in the diet, but also because, on a diet of uncooked fruits and nuts, he has rid himself of the most annoying indigestion, phobias, and irritable weakness, despite the concomitant of inveterate constipation, which is quite a common feature amongst vegetarians. When three or four years had elapsed, however, this gentleman had a breakdown in health, but after undergoing a rest-cure on a vegetarian diet with plenty of milk, he attained a condition of vigour to which he had been a stranger for many years.

Clinical Summary.—With such a record of cases I have not been able to escape the conclusion that whilst the purin-free diet is occasionally an admirable method of treatment in chronic cases of disease, it is not suited as a dietary for ordinary purposes of nutrition in everyday life. The cases admirably illustrate the old adage that “every man is a law unto himself,” and demonstrate the fact that most of them were extremely susceptible to the action of excess of purins in the diet; that when these were cut off completely, freedom was obtained from their particular malady; but that when malnutrition arose, their troubles returned with the old force. When they cautiously adopted a diet containing their old protein forms of food, with a minimum of purins, then they regained their health and strength, and because they were capable of dealing with all the purins they ingested, kept free or comparatively free from their malady. It is not necessary to suggest that this was due to an excess of uric acid in the blood or tissues, but simply that for some reason or other, probably toxic, they were unable to deal with these particular foods.

With this experience to guide me, I am now in the habit, in all chronic cases of disease in which the ordinary methods of treatment have yielded no good result, of cutting off all xanthin-containing and purin-containing articles of diet, which are at the same time non-nutritious or practically so—and this includes tea, coffee, meat soups, beef-teas and gravies.

The first three contain methyl-purins, which, although they add no uric acid to the excretions, increase very largely the total urinary purin-content. Nothing is lost by this means, because it has been proved that purins yield no potential energy and exert no influence on the circulation or nervous system, although they may temporarily remove feelings of fatigue, and because of their peptogenic effect slightly aid digestion. But they undoubtedly throw a great deal of extra work upon the organs of excretion, and thus cause a loss of energy, and by increasing the complexity of the digestive processes are liable to form toxins. I am strongly of opinion that when all these food accessories have been expunged, or nearly so, from the diet list, very little harm can result from the other purin-containing elements; and as these are chiefly proteins to which our digestion and tissues are accustomed, their deprivation is not lightly to be recommended—a fact which has been abundantly demonstrated in the series of cases I have just detailed. The conclusion of the whole matter would appear to be that the man who lives on simple diet in a moderate way is perfectly well able to deal with all the purins with which he is likely to meet. Octogenarians of all classes always declare that they owe their long life to the use of a simple, moderate diet, not depriving themselves of any ingredients, but using all cautiously, and indulging in hard work, many of them in the open air.

3. OBJECTIONS FROM A CONSIDERATION OF PURIN METABOLISM

An enormous amount of research work has in recent years been accomplished in connection with purin metabolism, and from its results we are quite clear that uric acid is the end-product of nuclear decomposition.

So far as one can judge by the results of extensive experimentation on man and animals, the sequence of events is somehow as follows:—The nucleic acid formed from the disintegration of nucleo-protein is acted upon by the ferment nuclease, thus liberating the purin bases. Guanin and adenin are deaminised by the ferments guanase and adenase when present—and the xanthin oxidases complete the process by

converting hypoxanthin and xanthin into uric acid. Finally a uricolytic ferment, varying in potency according to the tissue or animal in which it is formed, may attack the uric acid and destroy it. The liver appears to possess this uricolytic power in the highest degree, and although it may be present in the kidney, this organ is less liable to exercise this function than that of simple elimination. Uric acid in dogs is mostly excreted as urea and allantoin, although when the liver is cut out of the circulation by an Eck fistula, uric acid appears in the urine in considerable quantities, proving that it is normally oxidised in the dog's liver. Croftan declares, in opposition to Burian and Schur, that the human kidney apparently destroys more uric acid than the liver, and the muscles more than either—a striking commentary in favour of exercise, and a corroboration of the belief that the man who lives and works with his muscles in the open air can within reason eat any food he thinks fit. Even here, however, the excessive consumption of tea and meat soups and beer may occasion much of the rheumatism which is such a common feature of the working man's life; and Mendel has shown that alcohol taken at a meal delays the excretion of the purins, because it interferes with the destruction of nuclein. Purins are bodies of a highly complex chemical composition, and in excess form unusual combinations in the body which may act as irritants. Too little account is taken of the endogenous purins or those which are due to the daily wear and tear or metabolic activity of the cell constituents. They are the expression of that amount of protoplasmic activity necessary for the maintenance of cell function. Metabolism, as is pointed out by Dr. Hutchison, is not a hard-and-fast process proceeding along rigid lines to a definite conclusion, but a process as varied as temperaments, and marching in different individuals by different ways to diverse results.

It is clearly proven that exogenous purins—that is, those which exist in the food, both in a free and a bound condition—are excreted, the former very rapidly, and 50 per cent. of the latter in forty-eight hours. The other 50 per cent. is excreted as urea or bodies intermediate between uric acid and urea. Endogenous purins are said to be excreted in the same manner and the same time, but manifestly there can be no definite

information derivable on such a point. May they not be the cause of most of the trouble associated with uric acid? It is an interesting fact that most uric acid appears in the urine when the body is freshest—namely, in the morning hours and after a holiday. If, as we are informed by Haig, all the retained uric acid stored up in the tissues from the digestion of exogenous purins is expelled in—at the outside—twenty-four months when the patient is on a purin-free diet, then it is obvious that the trouble in many of the cases just detailed, if it were due to uric acid at all—must have been caused by endogenous uric acid.

This would prove that uric acid was not the cause of deficient metabolism, but the result. In most of the cases there was an undoubted diminution of tissue combustion, becoming increasingly evident the longer the purin-free diet was persisted in; and it is a notable fact that without exception they became much more susceptible to the influence of external cold. Dr. Haig naïvely asserts that those who practise his dietetic scheme can clothe themselves much more warmly without suffering from lethargic depression and debility—that, in fact, they are always active and lightsome. The truth appears to be that they are compelled to clothe more warmly because they cannot bear exposure to cold. I am not forgetting that many of his supporters contend that by eschewing purins in their food they are practically immune from nasal and other catarrhs. But, in common with the cases I have just detailed, there is no clear evidence that it was the diminution of purins *per se* that was the cause of any improvement in their condition, and I am inclined to think that, in addition, the following factors contributed to any good result obtained: (1) diminished amount of food; (2) diminished amount of protein; (3) greater attention to mastication and other laws of health previously ignored, such as expunging common salt from the diet.

Doubtless personal idiosyncrasy has much to do with the matter, as in other things, and it is a fact that exogenous purins are badly metabolised by gouty patients. But this is not the whole truth, for it has been proved that white meats like chicken and fish contain more purins than red meats, and yet the gouty man appears to suffer no worse results from the

former than from the latter: the reason, I believe, is that he can digest them much better than the larger-fibred red meats.

The pathology of gout is not nearly so simple as the purin-free advocate maintains, and it is quite certain that it originates in different ways in different subjects. It may have a renal origin or a metabolic origin, although in all cases there is a deficient purin metabolism, the purin bases being in excess in the gouty man's blood, even when he is living on a purin-free diet, so that while the endogenous uric-acid-content of the blood is raised, the total result is a diminished uric acid output. But perverted function of one or more organs of the body has much to do with the origin of gout, and it is conceivable that a blood charged with highly complex chemical substances like purins, or with toxic products of mal-assimilation, may, on physico-chemical grounds alone, render it difficult for the cells to get rid of their own waste products. The gouty man may inherit a perverted function of one or more of his organs, or the uricolytic enzyme may be inhibited or inactive, and thus his intolerance for purins may be explained. But there is no doubt that in cases not frankly gouty we can find the same intolerance as is instanced in most of these I have mentioned, and one can hardly escape the conclusion that in them cell-metabolism is at fault, and is rendered worse by the cells being bathed in blood already full of the very products which are endeavouring to escape from them—the outcome being a low endogenous uric acid output.

The digestion of animal food, especially meat, is in many cases interfered with by sugars, particularly cane sugar. In this way lactic acid fermentation is induced, and, the proteins being badly digested, it is quite possible for uric acid to be formed in greater proportion by a combination of the lactic acid and the highly soluble urea. People who suffer in this way should take as little carbohydrate as possible at a meat meal, or should consume their carbohydrates at a separate meal. Some support the theory that gout is caused not so much by animal foods as by the maldigestion of fruit and saccharine or carbohydrate foods, the kidneys being unable to excrete the compounds formed, and the tissue spaces being crowded with unmetabolised acid material very liable to precipitate. It is remarkable how quickly a plate of stewed

prunes or stewed rhubarb, with a liberal addition of cane sugar, will determine effusion into the joints. If such fruits really aid in alkalinising the blood, it is evident that their alkali does not favour freedom from rheumatic manifestations. It is important to note that uric acid is said to be held in solution in the blood by a chemically pure nuclein acid, viz., thymic or thyminic acid.

The rules for the treatment of gout, as laid down by Minkowski, may thus be summarised: The glandular organs, such as liver, kidney, and sweetbread, all of which contain large quantities of purin bases, must be rigorously excluded from the diet. A moderate amount of meat may be eaten, but wine, and especially beer, with its large content of nuclein in the yeast, should be eschewed. To clear away the purins excreted into the bowel, purgatives should be administered and diuresis should be promoted by copious water-drinking, so that the output of uric acid may be increased. He recommends a diet containing 100 to 120 grams of protein, 80 to 100 grams of fat, and a proportionately small quantity of carbohydrates, viz., 250 to 300 grams, altogether amounting to 2,200 to 2,600 calories. Pastries and rich food should be avoided, as well as medicines directed towards increasing the oxidation of uric acid or increasing its solubility, both of which are impossible.

In Chapter II. we have discussed already the action of enzymes in connection with the metabolism of purins, and emphasised the uncertainty of this factor. Mendel and Mitchell have demonstrated the existence of a uric-acid-splitting enzyme in both the spleen and kidneys of the ox, and show that uric acid is not destroyed by extracts of embryo pig's liver, nor boiled extract of adult pig's liver, but is destroyed by extract of adult pig's liver.

Of more importance, perhaps, in connection with my series of cases, is the fact that while many with powerful digestions and food assimilation can obtain their full allowance of nutriment from a fleshless diet, the average patient in this country cannot, and it is worthy of note that carbohydrate foods induce a greater amount of purin in the fæces than flesh foods, no doubt because they break down a greater number of cells in the intestinal mucous membrane, owing to the difficulty in

their digestion and absorption. May not this be one cause of the rheumatism so common in patients on a fleshless and tealess diet? It is certainly worth bearing in mind as a possible explanation of muscular rheumatism in all who are constipated, whether vegetarian or not, for if there be such a thing as auto-intoxication, then the endogenous purins may be absorbed. It may be of interest to note here that Burian suggests the constant production of hypoxanthin in muscle as the source of the endogenous purins, the hypoxanthin being oxidised to uric acid in the muscle.

In any research into the action of purins, the following considerations must always be borne in mind: (1) Personal idiosyncrasy has much to do with the diverse results reported, and in my opinion this is ultimately bound up with the metabolic activity of the cells, and especially the ability of the cells of the mucous membrane to withstand the onslaught of irritants such as purin compounds; (2) small quantities of purin are almost invariably well borne, and only in isolated cases are larger doses not tolerated; (3) the ability to tolerate purins is markedly influenced by disease—for example, neurasthenia, so-called, and kidney ailments where the integrity of the cells of the convoluted tubules is doubtful—yet a man in perfect health with a so-called gouty tendency may tolerate them badly, because they act as irritants to the mucous membrane of the hepatic ducts and produce hepatic insufficiency.

If the observation of Dr. H. C. Ross, that the absorption of xanthin by leucocytes (polymorphonuclear) and lymphocytes (mononuclear) is capable of inducing their division, is verified, an important contribution has been made to the rôle of uric acid and its allies in causing disease, because this induced cell-reproduction suggests the intense proliferation of tissue associated with cancer.

THE THEORY AND ITS INFLUENCE

Just as the vegetarians unblushingly claim all the advantages of the low-protein and purin-free theories, although the fundamental principle of each is absolutely in opposition to their own, so Dr. Haig avails himself of the athletic feats of

the vegetarians to demonstrate the merit of his system as a means unsurpassed for procuring physical prowess and regeneration. He succeeds in impressing the man of ordinary physical capacity with the belief that exclusion of purins from his diet will enable him to attain success in the athletic world, because by this means the circulation is not under the malign influence of uric acid. He agrees with the low-protein advocates in insisting that enough protein should be taken to subserve the nutritive requirements of the body, but differs from them in demanding that the quantity should be materially increased, *i.e.*, that 9 grains per pound weight of the body should be consumed in place of 6 grains. He objects to the use of otherwise excellent foods containing no purins, *e.g.*, eggs, because in his own person they increase the excretion of uric acid, and permits the use of foods containing purins, *e.g.*, potatoes, because they fail to increase his own output of uric acid. This is surely stultifying his own conclusions, and admitting the possibility that principles other than those he has emphasised may be in operation.

But with all its defects, the purin-free system marks a distinct advance in dietetic study and practice. It is an unquestionable fact that many people are quite incapable of metabolising purins, and it is at least doubtful whether this may not be one potent reason for the persistence of the cults of the fleshless feeder and the low-protein advocate. For its adoption a good digestion appears to be necessary, and it is notable that, where such does not exist, cures by its means cannot be safely prophesied. It is usual to find, also, that, after a cure has been effected, only the enthusiasts are willing to go on subsisting on such an unattractive diet. Its chief defect is its great monotony and absence of peptogens, and I have only known two people who had sufficient courage to continue it longer than a year or two.

It is certain, however, that there are many people who cannot live with any degree of comfort unless they approximate as closely as possible to just such a dietary. It would appear that, whatever the explanation be, the fuel must be accommodated to the furnace, and we are all acquainted with furnaces which can consume with ease whatever combustible is thrust upon them. But we recognise that there also exist fireplaces

which require a selected fuel of one kind or another before they can be calculated to do their work satisfactorily. So we find that many patients require special diets to rid themselves of certain of their ailments, and that these, unless they desire a recrudescence of their maladies, are compelled to adhere as closely as possible to a rigorous regimen. Having recognised their limitations and submitted to them, they may become more useful members of society than even those with much more effective assimilative functions.

Dr. Haig deserves much credit for so persistently bringing the study of dietetics before the medical profession, and especially for so forcibly evoking the attention of the layman to his excessive consumption of animal food. The dogmatic presentation of his doctrine has contributed to the physical salvation of many, even although his scientific explanations and deductions are neither warranted, corroborated, nor supported. It will be noted that although one of the important features of the system is that it insists upon a sufficiency of protein, the standard laid down, viz., 9 grains per pound weight of the body, is much less than that established by Voit, and more nearly approximates to the gram per kilogram of the body-weight now considered essential. An analysis of one of the typical charts detailed in Haig's shorter treatise shows an energy value of between 2,500 and 2,700 calories, well under the amounts until lately looked upon as necessary for the nutritive requirements of the body. Apart, therefore, from any specific influence it may be thought to exert, we may fairly claim the system as another powerful plea for moderation in eating.

CHAPTER VI

HYPERPYRÆMIA IN THEORY AND PRACTICE

THE doctrine of hyperpyræmia as enunciated by Dr. Francis Hare is really a counterblast to the three theories we have just discussed. Whereas they expend their energies anathematizing mainly the nitrogenous factor of the diet—the building material so-called of the body—Dr. Hare singles out the carbonaceous or heat-producing portion as the peccant element.

Definition of the Term.—The term “hyperpyræmia” is derived from the Greek word *pureia* (fuel), and is applied by Hare to a condition of the blood in which the circulating fuel—the heat and energy producing material—is in excess of the capacities of the organism for physiological disposal. The body, therefore, is practically saturated with combustible material, and only awaits a fortuitous spark to create a conflagration, which manifests itself as disease in some form, and to obviate such a catastrophe the carbonaceous income must be reduced. He usually effects this by greatly lessening the supply of carbohydrates, and although he may also at the same time diminish the proteins, they are generally in excess. A reference to Folin’s theory of metabolism will enable us readily to appreciate the reasonableness of such a doctrine, which otherwise would be in apparently open hostility to what had hitherto been considered incontrovertible facts.

The Salisbury Diet.—I shall revert to Hare’s method of dealing practically with the problem at a later period in the discussion, but meanwhile we must consider for a moment a somewhat similar practice with which Hare’s might easily be confused. This is known as the Salisbury diet, which in its

strictest form consists of lean beef and water, and was adopted in a purely empirical manner with the object mainly of preventing intestinal fermentation and the consequent absorption of toxic matters. In practice it differs from the hyperpyræmic doctrine chiefly in an enormous increase of the protein intake and a reduction almost to the vanishing point of fats and carbohydrates.

Salisbury alleged that starchy and fatty foods did not digest nor assimilate, but decayed and fermented, filling the organs with yeast, carbonic acid gas, alcohol, and vinegar, which afforded no nourishment to the system but induced disease and early death. He made the most extraordinary experiments on robust hardy working men whom he hired for the purpose, first, according to his own statement, producing disease in them by compelling them to subsist on the ordinary everyday diet, and then testing them with the elements of this diet administered one item at a time. In this manner he discovered that beef was the most easily digested, nourishing, and sustaining article of diet, and that the ailments of his hired men could be cured by putting them on a diet of broiled lean beef and hot water. He repeated his experiments on hogs, no less than one thousand of which he bought, and after feeding dissected, with a view to determining the most easily digested materials and those likely to yield the smallest number of toxic by-products.

His treatment of the sick consisted in the daily administration of four pints of hot water and, for a time at least, nothing else but 3 pounds of animal food, preferably minced beef. There were three meat meals each day, at 8 a.m., 1 p.m., and 6 p.m., and one and a half hours before each meal, and again three and a half hours after the last, one pint of hot water was taken. In addition to this it was imperative that a rest of nearly one hour's duration should be taken both before and after each meal.

He claimed that the hot water washed out the stomach, stimulated the liver and kidneys, promoted peristalsis, purified and liquefied the blood, washed out the uric acid, lightened the labours of the heart, because pure liquid blood was being circulated instead of sluggish, sticky, and congested material, diminished pain, and restored sleep. Some of these state-

ments are clearly fantastic, as is also his dictum that man is two-thirds carnivorous and only one-third herbivorous, because he possesses twenty meat teeth and only eight effective vegetable teeth. For this reason he contended that his diet should consist of two parts of animal food to one part of vegetable material, whereas the ordinary diet of everyday life contains about one-twelfth part of meat to eleven-twelfths of vegetable, fruit, and cereal.

He permitted the addition of a little white of egg to the meat, and if this diet is too restricted, then he allowed a piece of stale bread cut thin and toasted, with tea or coffee, without sugar or milk, as a substitute for water. As an alternative to the mince, not more than 1 pound of nicely broiled tender steak was suggested, with the addition of a little raw or well-stewed celery as an agreeable *bon bouche*.

It is well to enunciate the theory underlying the Salisbury diet, because it is in direct opposition to the allegations made by the vegetarians that the end-products of flesh foods in the system are of the most poisonous character, whereas those of carbohydrates and fats are simply carbonic acid and water, which are absolutely harmless. The fleshless feeders proceed on the assumption that the digestion and assimilation of the non-nitrogenous foods is carried to a complete finish, and they shut their eyes to the possibility of the formation of other acid end-products of a less innocent character. The occasional brilliant results obtained from a Salisbury diet after the patient has been unable to tolerate a mixed diet are a sufficient refutation of such a view.

THE SALISBURY SYSTEM CONTRASTED WITH HARE'S

It will be noted that while the Salisbury diet is administered with the object of diminishing the harmful effects of food in the alimentary canal, the hyperpyræmic theory applies to the food after it has been absorbed into the blood. Hare declares that excess of carbonaceous material in the blood is an essential, though by no means the only factor in many diseases, especially those of a paroxysmal character—migraine, asthma, epilepsy, bilious attacks, gout, and some catarrhs. He contends that carbonaceous compounds are much more

likely to accumulate in the blood than proteins, because the latter are excreted rapidly as urea. An excess of protein is easily disposed of because it tends to stimulate metabolism, and exercise and exposure to cold are essential factors in its metabolic disposal. Hence, in the absence of exercise and cold—conditions which in this ease-loving generation obtain to a large extent in the present day—an abundant supply of carbonaceous foods will cause hyperpyræmia unless fat be formed, and this can only happen to a limited degree.

He alleges that there are many reasons why such a blood condition should not supervene. In the first place an excess of carbonaceous material is apt to originate "glycogenic distention" of the liver, and by overfilling the portal system this causes congestion of the mucous membrane of the stomach and bowels, so that digestion ceases, or is restricted, and the supplies diminish. An excessive expenditure of carbon may also exist and act as a restricting factor, and this may occur during formation of fat, lactation, menstruation, or pregnancy. If these two means are insufficient for the disposal of the excess of carbon, disease arises, producing restriction by similar methods, *e.g.*, migraine, by causing indigestion and stopping the supplies, or asthma, by excessive exertion of the respiratory muscles increasing combustion. Acute gout, catarrh, and febrile attacks likewise increase combustion, and in this way disperse hyperpyræmia. The conditions which favour hyperpyræmia, therefore, are (1) a small carbonaceous expenditure, by reason of diminished combustion, and (2) a large carbonaceous income, due to eating a heavy mixed diet.

These two factors, he considers, explain why migraine and asthma are so apt to arise during the sleep which follows a heavy meal, while exercise and restricted diet tend to prevent both conditions. Typical attacks of asthma occur between 2 and 3 a.m., because at that time vitality, *i.e.*, combustion, is at a low ebb, and it is worthy of note that in those who turn night into day the conditions are reversed and the time of election for an attack is subsequent to sleep in the afternoon. Morning headaches disappear shortly after rising because of the increased combustion produced by the muscular activity required for dressing.

Conditions which are inimical to the production of hyperpyræmia are muscular exertion, exposure to cold, the presence of pregnancy, menstruation, lactation, glycosuria, pyrexia, and the formation of fat; and when hyperpyræmic disorders exist, they are rapidly cured by the supervention of one of these conditions. By increasing combustion Hare makes the trenchant observation that in a case of suspected tubercle with fever, where migraine, asthma, or even acne is present, one may safely predict that tubercle does not exist, but if these ailments should disappear, then the case is likely to be tubercle.

Both volumes of Hare's book will well repay the most careful study, replete as they are with the most interesting clinical material. The sketchy reference which I have made to the theory by no means does it justice, but it is probably sufficient for the purpose I have in view, and in any case, in fairness to its author, I must be content. One cannot help being struck with a certain family resemblance between this book and that in which Dr. Haig propounds his uric acid theory, a resemblance which I do not suppose for one moment is intentional. It is, however, a clear illustration of how an author, having formulated a theory, spares no effort to make every possible clinical fact fit into it as accurately as may be. Of course this procedure is not necessarily due to the theorist having forgotten that there is another side to the shield, for he is conscious that the greater the array of evidence he is able to produce, the more credible his theory becomes. His position, however, becomes all the more impregnable when he stops to consider the possible objections to his theory, and in justice to Dr. Hare, as we shall see, this is precisely what he does in many instances.

Theory Consistent with Moderation.—It is important to note at this juncture that although he is up in arms chiefly against carbohydrates and fat, he fully recognises that proteins contain a large amount of carbonaceous material, and while insisting on a liberal amount of proteins, he does not advocate excessive quantities, nor, indeed, much more than that represented by the Voit standard diet. It is well known that in diabetes sugar is formed from an exclusive diet of protein, and it is calculated that for each gram of nitrogen eliminated

2.4 grams of additional sugar appear in the urine. Lusk, as the result of experiment, satisfied himself that the sugar production from meat was equal to 58 per cent. by weight of the meat proteins metabolised, and contained 52.5 per cent. of its total available energy. To estimate approximately the amount of sugar excreted in the urine which is formed from proteins in the food, it is only necessary to double the quantity of urea; therefore, the combustible material contained in an excess of protein would equally tend to accumulate in the blood, establish hyperpyræmia, and be liable to induce the disorders incident to this condition. From this point of view, therefore, I consider Hare's theory as the most profound declaration in favour of simple moderation that has been advanced, and it is a fact of pregnant import that he does not proscribe any particular article of diet. In this regard he is in the same position as Chittenden. The one theory may be looked upon as the antithesis of the other—this emphasising the danger of excess of carbohydrate material, that of protein.

Objections to the Theory.—In connection with this contrast, it appears to me that we detect one of the objections to Hare's theory. He asserts that in common with every other function of the body the functions of digestion and absorption depend upon the supply of protein, and cites the case of dogs from whose diet all protein had been excluded, in consequence of which the food ceased after a time to be digested, and consequently remained unabsorbed. It is at least open to doubt whether by the selection of a typically carnivorous animal, whose diet includes a quantity of protein proportionally much greater than that of man, one is establishing a fair comparison. Besides, it is straining the analogy to a very fine point indeed, because it would be quite fair to respond that, the greater the quantity of protein supplied, the more effective would the functions of digestion and absorption become; and we know that this is not the case. He relies upon this statement to infer that on account of the restriction of protein, carbohydrates and presumably fats would fail to be assimilated, and hence that any good effects of vegetarianism, the low-protein diet, and the purin-free diet are to be attributed to the diminution of carbonaceous material in the blood.

Now, whatever may be alleged against the purin-free diet as promulgated by Haig, it cannot be said that it lacks a proper quantity of protein. It does not certainly contain as much as the Voit standard diet, but it has well over the gram per kilogram of body-weight now considered satisfactory. It suffers in no way from its quantity of protein. Its defects lie more in the fact of its exclusion of the peptogenic purins and the substitution of proteins to which the digestive organs are not accustomed. Again, during Chittenden's long experiment there is not the slightest evidence that there was any lack of absorption of fats or carbohydrates, although Benedict does suggest that an abnormally low protein supply may affect the absorption of nitrogenous material from the alimentary tract. But Benedict goes further, and asserts that the body absorbs the nutriment from food practically in the same proportions without regard to the amount ingested, whether that amount be large or small.

The vegetarian diet likewise, as served at Battle Creek Sanitarium, only contains 10 per cent. of protein to 30 per cent. of fats and 60 per cent. of carbohydrates, and yet the fæces contain no more than the usual proportion of undigested fat and carbohydrate, viz., 5 per cent. and 2 per cent. respectively. These facts have been proved abundantly by the daily examination of fæces carried out in the laboratory in a large number of cases over a very long period of time. So great, indeed, is the absorption of carbohydrate material in the case of vegetarians, that it is not at all uncommon to find that some of it escapes by the kidney, and can be detected as glucose in the urine. We should, therefore, find that vegetarians would suffer from hyperpyræmic attacks of one kind or another, whereas, on the contrary, we know that in them, at any rate, migraine and epilepsy are quite rare.

The vegetarian's explanation of this fact we have already considered, viz., that the carbonic acid resulting from the combustion of fats and carbohydrates is quickly eliminated through the lungs, while the products of protein metabolism are highly toxic products, which require for their elaboration and elimination a very considerable amount of work, in which not only the liver and kidneys are concerned, but various other organs. So long as these organs are fairly healthy and not

overtaxed with excessive quantities of toxin, it is hardly likely that they will be injuriously affected, or will allow the body to suffer. It is, however, conceivable that they may be almost continuously just below high-water mark, and in these circumstances a little extra dose of toxin, or even the absorption of some of the acid products of carbohydrate fermentation not pronounced enough to be noticeable as intestinal indigestion, would be liable to turn the scale.

It is necessary to emphasise the fact that although the ideal decomposition of carbohydrates has carbon dioxide and water for its end-products, this theoretical termination is never realised practically. Butyric acid, at least, is always found in the contents of the intestine, and if we are to judge by its acrid taste, its presence in excess is not likely to be unattended by discomforting sensations, and also other disagreeable toxic by-products. We also know that more than one alcohol and various acids, such as lactic acid, acetic acid, caproic acid, propionic acid, besides carbonic acid, are often, if not always, met with. We know that carbonic acid is quickly absorbed by the walls of the intestine and expired through the lungs without unpleasant symptoms, but that is no reason why the excretion of some of the other acids by the bronchial, gastric, or nasal mucous membrane should not be accompanied by asthma, bronchitis, biliousness, or nasal catarrh. Migraine and epilepsy may well be excited by the presence of toxins and various acids in the circulation, while the enforced starvation in the one case and the muscular contractions in the other may have much to do in destroying the toxins. It is remarkable how an alkaline purge, such as an old-fashioned magnesia or any of its modern prototypes, is capable of clearing the situation.

In any case, a moderate degree of restriction of the protein—and none of the systems we have been studying recommend more—cannot be considered as being accompanied by diminished digestion and absorption. It is hardly probable, therefore, that the reduction of the carbonaceous material of the blood is the explanation of the undoubtedly beneficial therapeutic effects of the three dietetic systems we have already discussed. I am inclined to believe that the valuable therapeutical influence of this dietetic system, as well as of the

other three, must be attributed to the diminished caloric value of the food in each. It is true that Hare recommends a slight increase in the protein allowance, but there is little danger of injury resulting from this moderate nitrogenous excess, accompanied as it is by an enormous lessening in the carbonaceous ration. If we calculate the caloric value of one of his daily diet prescriptions, *e.g.*, 8-12 ounces of cooked lean meat or fish, $1\frac{1}{2}$ ounces of bread or toast and a little butter, a little green non-starchy vegetable, a little tea or coffee with milk but no sugar, we find that it easily falls short of 1,000 calories, and this is practically starvation compared with any of the other three systems.

HYPERPYRÆMIA *versus* HYPERGLYCÆMIA

This is reducing the combustible material with a vengeance, and although the diet becomes more generous as the treatment of the case progresses, in a typical case it is always one of low caloric value. In these circumstances it is quite fair to question the existence of hyperpyræmia as it is conceived by Hare, *i.e.*, as an excess of carbonaceous material in the blood. The only available evidence would be in the detection of large quantities of glucose or carbohydrate in solution in the blood, apart from its appearance in the urine. We know that even in health the blood contains quantities of sugar not sufficiently great to be detected by ordinary clinical tests, just as the urine also always contains a certain amount of glucose in similar circumstances. We also know that in diabetes very large quantities of sugar—amounting to as much as close upon 8 per cent.—may be found in the blood, but this so-called hyperglycæmia, even when infinitely smaller quantities are present, is always accompanied by glycosuria.

We recognise that large numbers of people must eat an excessive quantity of carbohydrates without increasing their deposit of fat, without being afflicted with paroxysmal neuroses, and without suffering in any appreciable degree thereby. What constitutes the difference between those who can, and those who cannot metabolise the extra quantity of combustible material, and what becomes of it in those who dispose of it with impunity? We know that carbohydrates are the most

important source of muscular power, and fat the principal source of heat, although we are equally aware, in accordance with the Law of Isodynamics, that the different organic nutrients can replace one another in amounts as nearly as possible in proportion to their relative heat values. Rubner states the following as the quantities of the different food-stuffs which are isodynamic: Fat, 100 grams; starch, 232 grams; cane sugar, 234 grams; dried meat, 243 grams. We are absolutely certain in the animal organisms that fats are able to be manufactured from carbohydrates, and although not definitely proved, it is fairly certain that they also can be formed from albumin, while clinically we have no hesitation in saying that sugar is derived from albumin. We know that plants must synthesise albumins from carbohydrates and nitrogen, either extracted from the soil or, as in the leguminosæ, from the air; but we are equally certain that such transformations are impossible in the animal organisms. But the close relationship between lactic acid and alanine and other amino-acids, and the fact that synthetic changes which used to be considered a prerogative of plants are now known to take place at least in the kidneys, give us warrant for assuming that complicated synthetic processes of which we are as yet ignorant do take place in the animal cell. There may, therefore, be methods for the disposal of carbohydrates yet unknown to scientists, and this presupposition is at least as probable as the existence of hyperpyræmia.

Now Hare quite frankly recognises that the manifestations of hyperpyræmia are not associated with glycosuria, but that, on the contrary, the supervention of the latter is attended by a cessation of them, and hence hyperglycæmia excludes hyperpyræmia. He therefore relies upon Pavy's theory rather than that of Bernard, and declares that hyperpyræmia implies the existence in the protein molecules of the power to take on side chains of carbohydrate material, whereas when this power is lost we are in the presence of hyperglycæmia. The one condition, therefore, necessarily excludes the other. Hare confesses himself quite unable to reconcile these facts, but is content with the statement that hyperpyræmia and hyperglycæmia are antagonistic for the most part in their clinical relationships.

It is rather unfortunate that there is as yet no clinical evidence of the existence of hyperpyræmia, and I note that there is an entire absence of any appeal to chemistry in Hare's book. One is quite unable to refute the clinical evidence or the valuable therapeutical influence of Hare's dietetic suggestions, but it is quite possible on some other hypothesis than that of his theory. He expressly excludes the possibility of auto-intoxication, solely on the ground that there is no evidence of the existence of excessive intestinal fermentation. This, however, is by no means necessary, for toxins derived from proteins exist in the alimentary canal and are satisfactorily dealt with by the liver and kidneys, in a degree quite within the limits of health. There is no reason at all why a similar process associated with the carbohydrates might not be proceeding in such a manner as to disturb hepatic metabolism. The reduction of carbohydrates and fats in the foods simplifies the digestion in a very remarkable degree, and I have pointed out that Folin believes that some people have as much difficulty in metabolising carbohydrates as others have with proteins.

Besides, as Ryffel has pointed out, there can be no question that excess of carbohydrates is sometimes responsible for an accumulation of lactic acid in the blood, and there is no inherent possibility why some of the other acids associated with the decomposition of carbohydrates might not also be present, and set up inflammation or irritation in susceptible parts, or of some mucous membrane, perchance, during the process of excretion. I have recently had a case of severe asthma which derived no benefit from the purin-free diet, nor that associated with Hare's name, and yet was completely relieved by an exclusive diet of *Revalenta Arabica*. The assimilable protein in such a diet was not more than 14 per cent., and the daily calories never exceeded 1,000, so that ample opportunity was given for the body to rid itself of its toxins in the fortnight before the gradual resumption of an ordinary diet.

Allied Methods.—It may be that Dr. Hare has stumbled across the explanation of the great value of moderation in diet, and in any case he has emphasised the valuable therapeutical influence of an important dietetic procedure. Many

modifications of the system exist, but all alike ascribe their beneficial results to the diminution of toxæmia. One of the latest additions to the list is that of Dr. Ernest Young, who advocates an exclusive protein diet with hot water, in digestive disorders. He prescribes three meals of 2 ounces of minced meat, gradually and cautiously increased to 6, 8, or even 10 ounces, with the usual pint of hot water four times a day. He is careful to emphasise the fact that the diet must be regarded as a therapeutic measure only, an abnormal diet, helpful in restoring an abnormal condition of the digestion to the normal. When this has been achieved he advises that a mixed diet be resumed with as little delay as possible. This is judicious counsel when we realise that 6 ounces of lean meat per day has only an energy value of less than 300 calories, and even 30 ounces is well under 1,400 calories. Young recognises the objection to mixing carbohydrates and proteins in cases of dyspepsia, and suggests that in resuming the ordinary diet it is advisable to prescribe one entire meal of starchy foods in place of one of the meat meals.

Some of the treatments for obesity are characterised by an almost entire absence of carbohydrates. Towers Smith employed the following method. For fourteen days the diet was confined to rumpsteak, codfish, and as much as six pints of hot water per day. To obviate the possibility of dyspepsia the meat was made into an essence, as follows: Four pounds of lean beef were cut into pieces about an inch square and placed in a close-fitting, air-tight jar. This was placed in a pan of boiling water and allowed to simmer for six hours. The juice of the meat thus obtained was passed through a sieve and mixed with 4 ounces of the fibrin, which had been pulverised in a mortar. This was divided into four parts and administered daily. For the next twenty-one days the quantity of water was reduced to four pints, some vegetables and other kinds of meat were allowed; at the end of this time, and for thirty-one days more, the water was further reduced to two pints, and toast and biscuits permitted.

Saundby's modification of the Salisbury diet consists of 12 ounces of minced mutton, served as collops, divided into three or four meals, followed two hours later by half a pint of hot water. This is continued for two or three days,

during which the patient is kept at rest, and is extraordinarily successful in curing certain forms of dyspepsia.

The practice of zomotherapy, although distinguished by an entire absence of carbohydrates—except such small quantities as may be present in the form of glycogen—can hardly be included among dietetic methods allied to Hare's, as its use is founded on the principle that the muscle serum is possessed of antitoxic properties.

I had recently under my care a patient suffering from severe insomnia, in whom the only method of obtaining a few hours' sleep consisted in subsisting on the following apparently repulsive self-imposed diet: three meals per day, each consisting of 3 ounces of raw meat, 3 ounces of toast, and 2 ounces of butter. The slightest contravention of this regimen—even a departure so slight as the cooking of the meat—was invariably punished by renewed inability to sleep.

In contrast with the low-protein system and the two fleshless dietetic systems we have discussed, Hare does not recommend his diet as anything but a therapeutic measure, although he urges sufferers from the paroxysmal neuroses, migraine, asthma, epilepsy, &c., to approximate as closely as possible to a diet with a reduced intake of carbonaceous material. He is so particular in this regard that he impresses them with the disastrous possibilities residing in even two or three lumps of sugar, half an ounce of butter, a slice of bread, and he has been able to attribute an attack of migraine to the addition of only one of these items. He also emphatically urges the institution of means such as exercise, exposure to cold, diminution of sleep, and abundance of fresh air, with the object of increasing combustion. Some cases, of course, fail to respond to such a course of treatment, and a distinct proportion of such cases is what he categorises as *prepotent*. This term he uses to signify a class of case in which the fuel in the blood is discharged even when not present there in excess, in contradistinction to those he calls *postpotent*, where the conflagration only takes place when the fuel is in excess. In this latter class, while the temporary effects are unpleasant, the final result is beneficial, whereas in the former the results all round are disastrous and malnutrition ensues.

Reference must be made to his book for the best methods of recognising these cases and the therapeutic measures counselled. It is worthy of note that in many cases of malnutrition, forced feeding, with, of course, supervision of exercise and abundance of sleep—all factors contributing to the establishment of hyperpyræmia—is productive of the most brilliant curative results, although it is seldom that such cases are subjects of paroxysmal neuroses. The explanation of course is, that along with increased supply of pyræmic material, time has been given for the excretion of the accumulated excess of toxins, whilst no more fresh poisons have been formed than are capable of being excreted during the day, and so the metabolic functions have been stimulated to a point capable of dealing with the extra nutriment. The removal of the toxæmia, however, is here the factor of most importance, and it is astonishing to witness the daily regeneration of neurotic patients who have for years suffered from dyspepsia and constipation, and to note that confinement to bed is not inconsistent with a free and regular daily evacuation of the bowels. Such patients can tolerate with ease the temporary increase in the supply of protein, but I am hardly prepared to admit with Hare that the protein allowance in standard diets is inadequate, although, on the other hand, a more liberal protein ration in adolescence is essential to healthy adult life.

My own experience goes to show that cases of migraine and epilepsy make more assured progress towards recovery on a purin-free diet than on the diet recommended by Hare, although, when epileptics tend to grow stout, as they have a tendency to do on such a diet, they are in great danger of an attack. In their case excess of food, especially of animal food, is always bad. Cases of asthma, on the other hand, are better suited with a diet such as is suggested by Hare, the last meal being always a light one, and being partaken of not later than 6 p.m.

Acidosis.—Since the publication of the treatise which forms the text for the preceding remarks, and which emphasises the necessity for a limitation of the carbohydrates in the diet in certain diseases, quite a considerable literature has accumulated with reference to a pathological condition

of acidity which is unquestionably the product of an exaggeration of the very procedure advocated by Hare. As this condition of acidosis is most frequently associated with diabetes, it will be necessary to make a brief reference to this malady. Nowadays it is recognised that diabetes is not a single disease, and that glycosuria, which is the manifestation of a co-existing hyperglycæmia, is produced by many varied pathological conditions. We make a distinction between a mild and a severe form of disease, the former disappearing on a diet of meat and fat, plainly showing that the glycosuria was alimentary, and that the limit for the assimilation of carbohydrates had been reduced. In some, glycosuria only appears when sugar is eaten on an empty stomach; in some, it is averted by exercise. In others, glycosuria is only present when sugar is being absorbed from the intestine, indicating a weakening of the functions of the liver and an inability to convert the sugar quickly enough into glycogen.

Hyperglycæmia is generally attributed to a failure of the muscles to utilise the sugar presented to them, and this may happen even although the muscle cells are endowed with the usual ferment, probably because of the lack of a second necessary activating ferment. In any case, as much as one kilogram of sugar may be eliminated each day in a serious case of diabetes. The form in which the sugar is present is usually glucose, but it may be fructose, pentose, maltose, or even dextrin-like compounds. In very severe cases the urine possesses a peculiar fruity odour, now known to be due to the presence of aceto-acetic acid or diacetic acid, a substance which becomes converted into acetone by the loss of carbon dioxide. The occurrence of acetone in the urine (acetonuria) is not peculiar to diabetes, but is common enough in narcotic poisoning, *e.g.*, from chloroform, in digestive disturbances, cyclic vomiting, acute yellow atrophy of the liver, phosphorus poisoning, eclampsia, the vomiting of pregnancy, scurvy, typhoid and other fever patients, dysentery, cancer, inanition, and has been noted also even in healthy people who have been fed exclusively on protein and fat. It is, however, especially found in diabetics when the diet has been too suddenly deprived of carbohydrates.

The symptoms vary according to the rapidity of its onset, in slight cases loss of appetite, pain in the abdomen, nausea and constipation being present, and severe cases being characterised by progressive dyspnoea, somnolence, and sub-normal temperature. If recovery takes place naturally, it is because the organism has had time to form a sufficient quantity of ammonia to combine with and neutralise the acid, thereby keeping the reaction of the blood and tissues within normal limits. When, as in diabetic coma, death takes place, it is an example of true acid poisoning, both blood and tissues displaying a decided acid reaction. This is occasioned by the formation of β oxybutyric acid, which is only partially oxidised to diacetic acid, and both of these acids unite with the free alkalis of the blood, neutralising them and so causing the acid reaction. Hence during coma the amount of carbon dioxide in the blood is lessened and oxidation is diminished, as is evidenced by a reduced temperature and the excretion of other products of decomposition in the urine.

Naunyn applied the term "acidosis" to the appearance of large quantities of non-combustible organic acids in the urine, and this should be distinguished from "relative acidosis," an expression used to signify an abnormal excess of mineral acids over the fixed alkalis, or, in other words, a deficiency of alkalis. Harrower, whilst recognising that the blood never becomes really acid, proposes the term "acidæmia" for this condition of hypo-alkalinity, and asserts that it can always be discovered by an increase in the acidity of the urine—as evidenced by titration with decinormal soda—a diminution of the quantity of urea and an increase in that of ammonia. He believes that this condition is either actually due to or is very closely associated with intestinal autotoxæmia, and suggests a low-protein diet with intestinal antiseptics, alkalis, laxatives, open-air exercise, tonic hydro-therapy, and sodium succinate as a stimulant to the hepatic metabolism. The most important form of acidosis, as expressed by the quantity of acid products excreted, is that just described as associated with β oxybutyric acid, but the variety characterised by the presence of large quantities of lactic acid in the blood is scarcely less prominent, and as much as from 10 to 20

grams of this acid may be excreted in some liver diseases due to impaired hepatic function. In addition to this cause Ryffel, as we have seen, states that an accumulation of lactic acid in the blood may arise from an excessive supply of carbohydrates. During exercise sufficiently violent to cause dyspnœa, large quantities of lactic acid are formed in the muscles and, being absorbed into the blood along with an increased amount of carbon dioxide, all the signs of acidosis are produced excepting coma. In this way as much as .5 per cent. of lactic acid may be excreted by the kidney. But imperfect oxidation of any kind, such as a diminished supply of oxygen to the tissues or a diminished power of using oxygen, will produce the same effect. Lactic acid is always associated with the metabolism of carbohydrates and proteins, just as we shall presently see acetone bodies belong to the metabolism of fats. In a well-fed person, therefore, in whom such pathological condition exists, one expects to find an excretion of lactic acid and sugar, whereas in a person who is starved acetone bodies are encountered.

Other products of metabolism capable of producing acidosis in varying degrees are uric acid, oxalic acid, aromatic acids and fatty acids (lipacidæmia). All these acids being eliminated as salts in the urine cause the organism to lose a portion of its alkali, but as a rule this loss is easily covered by the alkali in the food or the reserve store in the cells. The normal alkalinity value of the blood is estimated to be about 300 mg. of NaHO for each 100 c.c., but, as Gamble has shown, this, in diabetics, may be reduced to from 200 to 230 mg.

The drain on alkali may exist for a long time without damaging the store in the system to any serious extent, and even in diabetes as much as 10 or more grams of β oxybutyric acid may be excreted in the urine for years without serious cause for alarm. But this is simply due to the fact that it is not the excreted acid which occasions the trouble, but that which remains in the body to exert its poisonous action, and it is of importance to note that neither the acetone nor the diacetic acid, which are comparatively harmless, are responsible for the poisoning, but the β oxybutyric acid alone.

Acetone is only occasionally produced from the fatty acids formed from the decomposition of proteins, for even when an excessive quantity of proteins is ingested the excretion of acid products is not very noticeable. But an exclusive diet of fats, sodium palmitate, oleic acid, or sodium oleate is rapidly followed by the excretion of large quantities of acetone, although the addition of carbohydrates suffices to diminish or altogether prevent their formation. Acetone and diacetic acid are oxidation products of β oxybutyric acid. Doubtless in normal circumstances oxybutyric acid is first formed, almost immediately oxidised to acetone and diacetic acid, and only in the presence of carbohydrates is the oxidation continued to carbon dioxide and water.

AUTOMATIC PROTECTION OF THE TISSUES AGAINST ACIDS

The tissues are able to protect themselves from the deleterious effects of acids by using an available alkali, ammonia, not absolutely essential for other purposes, and animals which manufacture a large supply of ammonia from their food can withstand acid intoxication longer than those forming less. Walter injected dilute hydrochloric acid into the stomach of rabbits, which are incapable of forming ammonia for protective purposes, and dyspnoea soon supervened, but this and other symptoms rapidly disappeared after a subcutaneous injection of bicarbonate of soda. As a result of the neutralisation of acids with ammonia, it appears in the urine in abnormally large amounts, and in this way becomes an index of the extent of the acid intoxication.

In most slight cases of diabetes the relation of ammonia nitrogen to the total nitrogen is 1 : 10 instead of the normal 1 : 16-33, but in more severe cases the ammonia nitrogen may be increased to as much as 25 per cent. of the total nitrogen. In ordinary circumstances the amount of ammonia in the urine depends on the adjustment between the acid products of metabolism and the supply of bases in the food, and whenever more ammonia is excreted than can be accounted for by the food ingested, then an abnormal amount of acid is being excreted. By far the larger proportion of ammonia formed from food is converted into urea, and in

proportion as it is required for neutralising acids the excretion of urea must suffer. Every gram of ammonia present in the urine in excess of the amount directly due to the food is equal to an excretion of 6.12 grams of β oxybutyric acid. The administration of alkalis can neutralise this acid, but cannot prevent its formation in diabetes, although when injected into the blood it can arouse a patient from coma.

Post-anæsthetic Acidosis.—The acidosis following anæsthesia is of intense importance, and is met with in two well-marked forms:—

(1) *Acute.* This is apparently quite sudden in its onset, intense restlessness, or in children screaming, supervening from eight to thirty hours after operation; but these symptoms are in reality preceded by a semi-comatose condition, which is usually attributed to the anæsthetic, and so much valuable time is lost in commencing the treatment. Rapid pulse, slight icteric tinge of the conjunctiva, a hay-like odour of the breath, persistent vomiting, and a rise of temperature combine to indicate the gravity of the condition, and examination of the urine reveals the presence of acetone and diacetic acid. Death takes place in from twelve hours to four days, and then the urine may contain leucin and tyrosin. This acute type occurs chiefly in children who have suffered from cyclic vomiting or some congenital lesion, although it may also arise in septic abdominal cases in badly fed adults.

(2) *Subacute.* This variety is much more common, and its presence is manifested by a rapid pulse and vomiting, often prolonged from two to four days, and the severity of which is proportional to the amount of acetonuria.

In delayed chloroform poisoning, the oxidation process is diminished in intensity, and the fats not being properly oxidised, their acids accumulate in large amounts. These acids increase the autolysis, and if this has had a good start and become fairly pronounced, then the exhibition of alkalis can only neutralise them, and does not suffice to repair the damage done to the tissues. As hepatic changes are frequently present, it is surmised that the liver is chiefly responsible for the formation or distribution of the acetone bodies. Embden has demonstrated by perfusing a recently excised liver with normal blood that acetone is found in the hepatic vein and

must therefore have been formed in the liver. This cannot happen in normal liver, so that profound changes must be present either in the shape of damaged cells or a diminished blood supply. In either case this means imperfect functioning and lessened oxygenation, and the fatty acids, being imperfectly oxidised, exhaust the store of alkalis, impair hepatic activity, and interfere with the glycogenic function, while in the effort to obtain the much-needed energy, the fats in the subcutaneous tissues are attacked. After death the glycogen is almost exhausted from the liver, and it is known that starvation and limitation of carbohydrates can deplete the store of glycogen.

Acidosis, therefore, may be said to be due to a lack of carbohydrates in the food, or a lack of ability to use the carbohydrates, or, still further, an increased capacity for consuming the fat of the food or the body. Its pathology is still somewhat uncertain, but what is fairly clear is that the body is incapable of completely metabolising fats excepting in the presence of carbohydrates.

Diet in Diabetes.—The remedy is equally clear, viz., to increase the supply of carbohydrates, a simple enough process in certain circumstances, but one requiring considerable caution in diabetes. In the mild form of this disease, as ascertained by estimating the amount of sugar in the urine and the absence of acetone bodies, a rigid diet as free from carbohydrates as possible should be adopted. If this checks the excretion of sugar, then a little ordinary bread is gradually added to the diet, and the quantity consumed just before the reappearance of the glycosuria is a measure of the carbohydrate food which can be tolerated by the patient. In the severe forms of the disease, too strict a limitation of the carbohydrates, especially when a diabetic is in bed, is a risky procedure, so that a few days must be allowed to elapse before changing from a mixed to a rigid diet. The ideal diet for such cases is nitrogenous food, and fatty food with a small quantity of carbohydrate, saccharine food being entirely avoided.

The rationale of all the dietetic systems for diabetics, such as the oatmeal cure, the preference of potatoes over bread, &c., can easily be comprehended from a consideration of the above facts. In diabetes an important object of quest is the discovery of less harmful energy-producing substances to replace carbo-

hydrates, and lævulose, oatmeal or potato starch, citric, lactic, glutinic, and glyconic acids can all do this to a certain extent. A great desideratum is a practical substitute for sugar and sugar-yielding foods, and glycerine, glycerine aldehyde, and alcohol have all been recommended, but it should be noted that the last mentioned is a poison. It is believed by many that the carbohydrates are tolerated in the following order of acceptability: lævulose, lactose, starch, cane sugar, grape sugar, and galactose, the last three being especially badly borne. Clinical experience, however, hardly corroborates this testimony, and it is well known that in some cases the sugar formed from albumin is more detrimental than carbohydrate sugar. For this reason diabetics should never eat more than 150 grams of protein per day. Amongst vegetarians, both in India and elsewhere, it is customary to use cocoanut and other oleaginous seeds as a substitute for animal proteins, and they claim that the treatment of diabetes in mixed feeders is much more successful when meat, alcohol, tea, coffee, and cocoa are withdrawn from the diet.

The lower fatty acids—butyric, iso-valeric, caproic and perhaps acetic acid—increase the acetonuria, and butyric acid may be changed directly into β oxybutyric acid. In very severe cases therefore butter, which contains so many of the lower fatty acids either free or as triglycerides, should be used fresh and after washing, never old.

When there is a threatening of coma, dextrin may be injected per rectum and alkalis administered. The most convenient form of alkali is a combination of bicarbonate of soda with half as much bicarbonate of potash and the addition of one-twentieth as much of the carbonates of calcium and magnesium. The quantity of bicarbonate of soda, in excess of 2 drachms, necessary to render the urine alkaline is a good measure of the degree of acidosis, and in extremities it should be remembered that subcutaneous or intravenous injections are methods of greater certainty.

To prevent the occurrence of acidosis after anæsthesia, especially in susceptible subjects, it is requisite to see that the patient does not proceed to operation with the stomach empty, but a fairly substantial meal, always containing carbohydrates, such as a plate of rice pudding, should be supplied shortly

before the appointed time. In children the urine should be tested for acetone by Legal's method, and when present the operation should be delayed until, by the administration of glucose and bicarbonate of soda in drachm doses every two hours during the day, the acetonuria disappears.

In urgent cases glucose can be administered by the rectum, or advantage can be taken of the glucose tubes which can now be purchased and are employed for making solutions for use by hypodermoclysis.

It is instructive to contrast the two dietetic procedures described in this chapter—the one insisting on the limitation of the carbohydrates, the other deprecating too strict a limitation of the same food substances and enlarging on the danger incident to such a course in certain circumstances. It is an example of the ease with which the metabolic equilibrium may be disturbed, a warning not too rashly to ignore the nutritive requirements of the body, and an apt illustration of the necessity for a well-balanced ration suited to the indications of each individual case.

CHAPTER VII

DIETETIC THEORIES ASSOCIATED WITH THE MINERAL SALTS

IN the dietetic theories we have already discussed, our attention has been riveted mainly on the three essential alimentary principles, and each theory has been concerned with the disposition, from its author's point of view, of these items in the most effective proportions. It has been generally assumed that when the correct amounts respectively of protein, fat, and carbohydrate have been ascertained and the appropriate kind of protein has been settled, the foods which it is decided should be used as nutrients will contain all the mineral salts that are required. Even when it was demonstrated that such calamitous diseases as scurvy were more or less dependent upon the saline content of the food and were perfectly amenable to treatment by the addition of lemon-juice to the dietary, little heed was paid to the rôle of mineral salts in dietetics.

This is, however, hardly calculated to excite much surprise when we reflect on the enormous difficulties likely to be encountered in the course of such investigation, considering how little we know with absolute certainty of metabolism within the individual cells, of the term of existence of any single cell, or the length of time its bioplasm may persist. Much ingenuity and patient research have been displayed in tracing the proteins, fats, and carbohydrates through their manifold transformations till they find a home in the tissues or are utilised as sources for the production of energy, and we recognise that the term "food" must be held to embrace not only energy-producing substances, but anything that can enter into the composition of the cells. For this reason both water

and the mineral salts must receive the designation of foods, and although the necessity of a constant supply of the former is obvious, constant renewal of the latter might at first sight be considered less compulsory, as the possibility of using anew the salts liberated from the waste material of the cells must be borne in mind.

Indispensability of the Mineral Salts.—Many experiments have been devised to illustrate the indispensability of the mineral salts in nutrition. Forster fed two dogs on fat, starch, sugar, and meat left over from the preparation of Liebig's Extract of Beef, this residue having been repeatedly boiled with water until it only contained .8 gram of ash for every 100 grams of dry substance, with the result that the animals died sooner than if they had been starved to death. Pigeons fed with casein and starch met a similar fate. Bunge suggested that the fatal termination of the experiment was not due directly to lack of salts, but indirectly, because the sulphuric acid due to the katabolism of tissue protein extracted alkalis from the cells and so produced their disruption. Even with less ash in the food he argued that were a sufficient supply of alkali to unite with the sulphuric acid administered, then death should at least be delayed. The experiments were accordingly repeated by Lunin, with the addition of various alkaline salts, and the proposition was found to be accurate. Nevertheless, it was proved in the case of mice, at any rate, that life cannot be sustained without the addition of salts to the food, and that even by adding artificial salts the inevitable result was only delayed a short time.

Much other evidence exists to demonstrate that although mineral salts are unable to furnish the body with energy they are quite as important in nutrition as the better known food-stuffs, and that they subserve many complex functions in the economy. The proteins, fats, and carbohydrates may be regarded as the rank and file of nutritive substances, while the mineral salts are the executive officials responsible for the accomplishment of effective work ; but it is less easy to ascertain the exact proportionate quantities necessary for functional efficiency than it is to officer a military unit. In the absence of research and accurate information, irresponsible theorists have occupied the ground with misleading conceptions, but

happily these are fast vanishing in the face of the renewed attention given by physiologists to the subject.

Erroneous Views of Unscientific Writers.—There are many lay writers on dietetics who have promulgated the view that all disordered conditions of the blood are due to an excess of salts in the food, and particularly to an excess of acid salts. In considering the uric acid theory I pointed out how frequently the inclusion of some highly acid fruit in a meal will determine an attack of rheumatism, and the conception just mentioned is simply a reflex of the uric acid theory that the body is capable of storing up somewhere in the tissues its acid waste matters. There is, of course, no physico-chemical evidence of this, while there are many facts which point to a contrary conclusion.

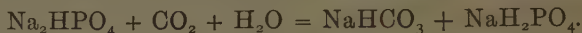
Chloride of sodium is especially blamed for being a "retentive of uric acid," but all the other salts, natural or otherwise, are looked upon with grave suspicion. Hence on the grounds that they are neutral, starchy foods are commended in preference to meats to all invalids or delicate people, but strong people are counselled to adhere to them for the purpose of helping to expel their stored-up acids, and it is even claimed that these foods have the faculty of neutralising such acids in the system. It is easy to recognise in this statement the theory that carbohydrates are the most suitable foods for those suffering from hyperchlorhydria, ignoring or oblivious of the other theory that proteins exclusively are the correct aliment, because they combine with the free acid, and entirely forgetful of the fact that a preponderance of starchy food may quite as easily lead to the production of organic acids, such as lactic, acetic, &c.

Sodium Salts.—It is opportune here to take cognisance of the fact that chloride of sodium is a most important factor in the production of hydrochloric acid in the stomach, and it has always been a puzzling problem to account for the formation of a free acid from the alkaline blood and lymph. Maly's theory is, perhaps, the most satisfactory explanation and can be easily understood by a short study of the following formula:—



i.e., the action of sodium dihydrogen phosphate upon chloride of sodium produces disodium hydrogen phosphate and hydro-

chloric acid. In all probability the sodium dihydrogen phosphate is itself derived from the action of the disodium hydrogen phosphate and the carbonic acid of the blood in this fashion—



It is evident, therefore, that restriction of the consumption of chloride of sodium is an element of considerable importance in the cure of hyperchlorhydria.

Sodium salts are usually regarded as being much less depressant than the corresponding salts of potassium, but they are looked upon with some suspicion, in common with those of potash, in the treatment of gout. Falkenstein treats this disease by large doses of hydrochloric acid taken as acidulated water during meals. In his recent work he quotes the experiments made upon rabbits by Von Loghen, in which artificial gouty foci were made by injecting a solution of uric acid, after which some of the animals were treated by hydrochloric acid and some by alkalis administered by the mouth. They were then killed, and upon examination it was found that in those treated by alkalis the uric acid had been converted into urate of soda and the deposits were surrounded by a considerable amount of inflammation, whereas in those treated by acid the uric acid was unchanged and no irritation was evident. This, however, as also the new method of treating disease by sea water injections, encroaches rather on the domain of therapeutics, although not without dietetic significance.

Less equivocal and more decidedly related to our special sphere is Pavlov's observation of the inhibitory influence of the alkalis on the digestive glands, entirely controverting the doctrine that alkalis administered before a meal have the power to stimulate a flow of gastric juice. This erroneous belief was apparently fostered by omitting to take into consideration the stimulating effect of water itself, with reference both to the gastric and pancreatic juices, and also failing to note that hypersecretion is an accompaniment of most functional disorders of the stomach.

THE SALT-FREE DIET

The Craving for Salt.—Chloride of sodium likewise enjoys the distinction of being the only inorganic substance which it

is necessary to add to our diet. This is all the more remarkable because both animal and vegetable foods contain considerable proportions both of sodium and chlorine, but the explanation is to be found in the decided preponderance of potash in vegetable foods as compared with the content of sodium. We have already dealt with this subject fully in Chapter II. in connection with Bunge's theory, but it may be profitable to add a few more details just at this point. It is notable that only the true herbivora and not the carnivora crave for salt, despite the fact that the chloride of sodium content in the food of both classes of animals is practically the same. The only factor in operation is the three or four times greater quantity of potash contained in the food of the herbivora, producing a double decomposition with the chloride of sodium in the blood, so that to preserve the chemical composition of the blood, the compulsory excretion alike of the chloride of potassium and the newly formed sodium salt takes place, thus depriving the serum of its necessary sodium chloride.

It may be taken for granted that this theory is correct, despite the fact that rabbits and hares live on foods rich in potash without craving for salt, and that cows and sheep can remain in perfect health on a similar diet without any addition of common salt.

It has been suggested that although the blood serum of carnivora and herbivora alike contains similar quantities of soda and potash, viz., $\cdot 43$ per cent. of soda and $\cdot 026$ per cent. of potash, the fact that the red corpuscles of certain classes of herbivora contain considerable amounts of soda is a sufficient explanation of this craving for salt. On the other hand, the red corpuscles of the carnivora also contain larger amounts of soda than those of the horse, cow, rabbit, &c., which subsist on foods rich in potash, without craving for salt. It is a notable fact that in the milk of the carnivora soda and potash are almost equally represented, whereas in the milk of the herbivora, as in human milk, the potash is to be found in greater proportion, so that from the moment of birth their respective organisms become accustomed to a fixed relation between the amounts of potassium and sodium. Hence the carnivora, eating the entire animal, consume almost equal proportions of

the salts, whereas the herbivora and man, subsisting on many foods with a preponderance of potassium, adjust their organism to this relationship. There is no doubt that some automatic method must be in existence for regulating the soda and potash content of the blood, as well as doubtless of its other equally essential salts.

Osmosis and Common Salt.—No more fitting illustration of the paramount importance of mineral salts in the human economy can be found than the influence exercised by chloride of sodium on tissue metabolism and the composition of the fluids of the body. The accumulated results of recent researches go to show that when consumed in quantities above the physiological limit, common salt is retained in the tissues, and that as this cannot take place in the form of crystals of sodium chloride, but only in solution, water must perforce be retained in proportion to the amount of salt. Hence the tissues become more watery and the body-weight increases.

Chloride of sodium is found almost universally throughout nature, and is a constituent of all animal and vegetable tissues, although the latter are relatively poor both in sodium and chlorine, as they contain only a quarter as much as animal organisms. In the human body it displays a preference for the fluids, blood serum containing about 6.75 grams per 1,000 and cerebro-spinal fluid almost as much. Chlorine is also an important constituent of the red blood corpuscles, but in them it is found in association with potassium, there being as much as 3.67 grams of chloride of potassium in the erythrocytes of an adult. Chlorine is found less abundantly in the tissues, although the body of a man weighing 70 kilograms contains on an average about 200 grams of chloride of sodium, with somewhat less chloride of potassium, the former being found chiefly in the fluids and the latter mainly in the tissues, especially the blood corpuscles, muscles, and the nervous tissue.

The quantity consumed in the food varies greatly in different nations, as much as 20 grams daily being quite common in most European countries. This is rapidly excreted in normal circumstances by the kidneys, and in the sweat, tears, and faeces, whilst pathologically it appears in the expectoration, vomited matter, and diarrhoeal stools. During

health the body excretes the chlorides of the food with great rapidity, and so the proportion in the tissues and the fluids remains fairly constant.

As the chlorides of the body circulate in a state of solution, all gains or losses of chlorides involve a gain or loss of water, and as chloride of sodium passes through the body without undergoing any chemical change, it is thus in the position of being able to control osmotic changes within the economy. Hence it follows that the blood and tissue fluids may be isotonic, hypotonic, or hypertonic in relation to each other, in accordance with the content of chloride of sodium. In addition to this all-important function, it is stated to exercise an antitoxic influence, protecting the tissue cells against the action of poisons.

Only a small daily dose is actually necessary to renew the quantity contained in the body. Bichat says this should not exceed 2 grams, although in health it may sometimes be of advantage to take a little more, and von Noorden suggests 3 or 4 grams as the minimum amount. When less is habitually excreted than is ingested, then retention takes place and a state of hyperchlorination exists. When more is excreted than is ingested, we have the somewhat rare condition of hypochlorination. This can only be induced slowly by a dechlorinated diet, and is accompanied by loss of weight, emaciation, polydipsia, and polyuria.

Hyperchlorination.—The regulative action whereby in health an excess of chlorides is quickly eliminated by the kidney is for some reason suspended during various diseases, and the condition of hyperchlorination is comparatively common.

Experiments on animals have demonstrated that an excess of chlorides introduced into the circulation is not able to escape with sufficient rapidity through the emunctories, but as the blood refuses to tolerate more than a certain proportion, the excess is excreted, so to speak, into the tissues, and therefore chlorine accumulates in the system. It has been sought to explain this phenomenon by stating that the chlorides combine partly with the albumins of the blood, which are increased during disease, and so form compounds incapable of excretion by the kidneys. But no increase of

chlorides can be noted in the blood except for a few hours after absorption, although hyperchlorination is always associated with a heightened specific gravity of that fluid.

The retention of chlorides in the tissues has been explained in various ways, one or more of which may be in operation at the same time. It is not always dependent on inefficient renal activity, although the diseased kidney probably is less capable of excreting chlorides than the healthy kidney. Probably it is induced by interference with metabolic activity, for it is known that retention of chlorides may be secondary to the presence in excess of other producers of disassimilation. Besides, the retention may be local, as in ascites.

Widal has shown that a diseased kidney is relatively impermeable to chlorides and the products of nitrogenous metabolism, and cases of renal disease have been classified in accordance with difficulty of excretion of chlorides, of urea or of both substances. In the case of chloride of sodium, the salt passes back into the tissues to keep the tissue fluids isotonic with the blood serum. Urea, on the other hand, remains in the blood until its partial pressure or percentage proportion is sufficiently high to enable its ions to be absorbed by the renal cells and thus excreted, or in any case until the urea-pressure is high enough to force a passage. As chloride of sodium thus accumulates in the tissues and urea in the blood, it is easy to distinguish the two conditions, because in well-marked chloride retention there may be no excess of urea in the blood. If there be in the blood 2 to 4 grains of urea to the pint of serum ($\cdot 3$ to 600 grams), we are dealing only with chloride retention, but if we find 8 or more grains to the pint ($\cdot 6$ to 600 grams), then there is nitrogenous retention, while if it reaches 20 or 30 grains (1.6 or 2 to 600 grams), then death is imminent or probable.

Excess of chloride of sodium in the body raises the blood-pressure, although this may be only temporary. This saline hydration then induces œdema and may even cause albuminuria, but as it is stated to diminish the toxicity of certain endogenous poisons it may act as a defensive agency. A local excess is always irritating and may induce emesis or purgation. Physiological saline solutions are not painful because they are isotonic to the vital media, whereas

hypertonic and hypotonic solutions generally create discomfort.

Moderate doses of salt, *i.e.*, from 2 to 4 grams per day, increase metabolism and appetite, but they have also a tendency to diminish digestive activity. Although a sufficient quantity must be taken to keep up the supply of hydrochloric acid, still it is hardly possible to add too little to the food, and people have been known to exist for years without adding a grain to their vegetarian diet. Even when partaken of to excess, *e.g.*, in diabetes, the body sustains no injury because it is easily excreted. In such conditions, however, it may irritate the digestive and other mucous membranes, and it is notable that diabetics and glycosurics are prone to attacks of nasal, pharyngeal, and bronchial catarrh. Christison reported a case of death in a man twenty-four hours after having swallowed a pound of common salt.

A hyperchloric diet excites the appetite, stimulates diuresis where the patient is free from chloride retention, and fixes water in the tissues where there has been emaciation from dehydration. For this purpose, for example, in infantile enteritis Mery proposes the following clear soup: Carrots and potatoes 60 grams, turnips 25 grams, peas and beans 25 grams, water 1 litre. Boil these ingredients for four hours, drain off the water, and add salt in the proportion of 5 grams to the litre. When this is prepared fresh and given to children with choleraic diarrhoea (infantile enteritis), it fixes water in the tissues.

In his investigation on Bengali prisoners, who, it may be recalled, were pure vegetarians, Major McCay concluded that a large ingestion of salt in the diet is accompanied by an increase in the body-weight, an increase in the excretion of the urine, and a marked increase in the amount of salt eliminated by the skin. The quantity of chlorides in the fæces was constant, had no relation to the amount in the diet, and in any case was very small, only half a gram daily. He noted that there was practically complete absorption of the salt added to the food, whether the amount was large or small. He suggested that the salt ration should be regulated by the quantity excreted by the skin, and when this is found to exceed normal limits a reduction should take place in the allowance.

Engel's observations are of undoubted interest in this connection. He injected into the veins large quantities of 6 per cent. chloride of sodium solution, and found that all the tissues except the bones became more watery. The muscles, which represent about 40 per cent. of the weight of the body, absorbed quite two-thirds of this water and yet continued to perform their normal functions.

Dechlorination.—A hypochloric—or as it is more frequently designated, a dechlorinated—diet is of great value in many diseased conditions, but notably so in epilepsy. In this malady it is most useful for increasing the effects of the bromides, bromine being able to replace chlorine in the fluids and tissues, and indeed rapidly hasten its excretion from the body. This is proved by the fact that in experiments on animals the administration of bromine is followed by a marked decrease of chlorine in most of the organs. Chlorine and bromine mutually displace each other in the tissues, and Laudenheimer found that after the administration of 70 grams of NaBr in seven days, 36 grams were retained, and 26 grams of sodium chloride were liberated and excreted. In the treatment of epilepsy it is not necessary to exclude all the chlorides from the diet, but it is always wise to refrain from adding chloride of sodium to bread, replacing it by bromide of sodium in the proportion of $1\frac{1}{2}$ to 2 drachms to the pound. Ordinary bread contains from 5 to 6 grams per kilogram (about half a drachm to the pound), while in dechlorinated bread not more than 10 centigrams per kilogram should be found.

Food-stuffs containing Chloride of Sodium.—It is essential for the correct application of the salt-free diet to possess a knowledge of the chloride contents of the more common food-stuffs. Chlorides are present in beef-tea in very large quantities, but raw meat contains only an average of 80 centigrams per kilo (5 grains to the pound), and even this may be completely separated from it by boiling. Fresh-water fish contain only half the quantity to be found in raw meat, but salt-water fish are naturally rich in chlorine. In milk 1.85 grams per kilo (12 grains to the pint) of common salt are present, and in butter from 1 to 14 grams to each kilogram. There is none at all in sugar, only traces in cocoa

and chocolate, while fruits and most pure carbohydrate foods contain very little, rice and potatoes particularly only possessing 2 centigrams per kilogram. The pulses and vegetables contain half as much as milk, and eggs weighing about 50 grams (about 2 ounces) contain only one-eighth of a gram or about 2 grains.

Each case of epilepsy must be treated on its merits, and various modifications of the diet have to be recommended. Milk, butter, fruit, eggs, and bread salted with NaBr, to which may be added vegetables, minced meat, and ordinary butcher's meat when a distaste is developed for this regime, is a favourite diet list with some medical men. Others again prefer an entirely vegetarian menu. Chalmers Watson gives the following sample of a salt-free dietary:—

Breakfast.—Porridge and cream, flavoured with syrup or sugar, cup of tea with plenty of milk, toast or roll specially prepared, and butter.

Lunch.—Eggs or prairie oysters, or egg-flip, or sweet custard or roast chicken, with toast or roll as above, potato or tomato. Any farinaceous milk pudding, or jelly or cream.

Afternoon Tea.—Cup of tea with wafer of toast or sponge biscuit.

Dinner.—On the same lines as lunch; chicken not to be taken oftener than once a day.

It is unwise to continue the dechlorinated diet for too long a period, as nutrition must ultimately be interfered with, and in some cases aggravation of the malady arises.

A dechlorinated diet is useful, if not imperative, in interstitial nephritis, dropsy from heart disease, hepatic disease, tubercular peritonitis, pleurisy, eczema, phlegmasia, glaucoma, hyperchlorhydria, hay fever, coryza. Unless the salt supply be limited to .6 gram chlorine, equal to 1 gram of sodium chloride, such a diet does not always secure hypochlorination of the body, because local causes may be too powerful, so that it is always wise to supplement it by diuretics, *e.g.*, theocin-sodium-acetate with digitalis and purgatives, diaphoretics, and even local puncture. It is often useful to alternate a saltless diet with a milk diet, and it is judicious to weigh the patient regularly and see that other condiments, such as pepper, mustard, and vinegar, are not substituted. One must be care-

ful in prescribing a diet such as this to insure that correct methods of cooking are employed, and that no salt be added in the kitchen. Meat may be eaten raw or roasted with fresh butter, or boiled and seasoned with a very little vinegar, or a little nitrate of soda may be added at the table. Potatoes may be baked and eaten with fresh butter or made into a purée with fresh butter. Boiled potatoes may be substituted for some of the bread usually eaten. Cheese should always be prepared fresh.

Common Salt an Aid to Absorption.—Besides its function of increasing the absorption of water, it is known that common salt is a powerful adjuvant to the absorption of albuminous substances. Pure water is absorbed very slowly by the bowel wall, but a dilute solution of common salt is rapidly absorbed, and a rectal injection of pure albumin is not absorbed until a little common salt is added, when it is rapidly sucked up by the bowel wall. It is stated that the long-continued use of vegetable foods in Central Africa creates such a painful desire for salt that when the natives are deprived of it for any length of time they begin to show signs of insanity. Whether this be due to the retention of toxic materials is decidedly doubtful, but many hold the belief that common salt is necessary for the excretion of toxic products. During many diseases an excessive elimination of chlorides by the urine is considered to be an excellent prognostic sign, because the toxins are excreted with them, while on the other hand retention of chlorides is one of the most frequent signs of auto-intoxication.

Those who advocate the use of large quantities of added salt declare that it induces a healthier appetite, a stronger digestion, and a much more vigorous physique than in those who only use this condiment sparingly. They are particular, however, not to attribute all the good effects to the chloride of sodium *per se*, but to it in combination with various salts, such as phosphates, iron, &c. There are those again who deliberately declare, on the flimsiest of evidence certainly, that the causation of cancer is bound up with the consumption of common salt. Probably the truth, as usual, lies somewhere midway, and it may be that there are some who display the irritant effects of common salt on the mucous membranes with great readiness, and these certainly should eschew it in daily food.

The addition of a moderate amount of common salt to the food in health is not only not injurious, but, as the balance of the evidence shows, distinctly beneficial.

Potassium Salts.—Potassium salts are as essential to the nutrition of the body as salts of sodium, and are probably in great measure able to replace them, but our knowledge on this point is not in a very advanced state. Bunge, who is at present engaged in research on the subject, gives a table of the proportion of sodium to potassium in certain foods.

To one equivalent of sodium there is—

In yolk of egg		1 equivalent of potassium
„ milk		0.8 to 6 equivalents
„ veal		4 „
„ wheat		12 „ 23 „
„ potatoes		31 „ 42 „
„ peas		44 „ 50 „

There is a fairly prevalent belief that it is unwise to include too much potash in our diet because of its depressant effect. Whatever truth there may be in this belief, it must surely be confined to its employment as a drug, and we know that in large doses potassium salts are pure protoplasmic poisons, specially acting upon the more highly organised nerve centres and the heart muscle. But there is no evidence that such foods as beans, peas, lentils, and potatoes in moderation act in a deleterious capacity because of their potash content.

Scurvy.—Scurvy has been repeatedly ascribed to a deficiency in the potash salts of the food, producing a relative acidosis, but its etiology is still obscure and has been equally attributed to ptomaine poisoning and specific infection. Whatever its causation, however, it is known that a plentiful supply of fresh vegetables and of fresh meats cures the disease, and it is probable that potash is useful, less for its own sake than for the vegetable acids with which it is usually associated, and which by their oxidation induce a proper degree of alkalinity of the blood. It is important to remember the distinction between vegetable food-stuffs on the one hand and meat and cereals on the other. The characteristic of the former from our present point of view is an excess of base over mineral acid, and of the latter an excess of mineral acid over base, so that deprivation or insufficiency of vegetable foods tends to

diminish the alkalinity of the blood and interfere with its power of coagulability. Wright has divided foods into three groups according to the reaction of their ash as determined after incineration:—

- (1) *Acid Foods*.—Barley, beef, eggs, maize, oats, rice, wheat.
- (2) *Neutral Foods*.—Animal fats, sugars, vegetable oils.
- (3) *Alkaline Foods*.—Beans, blood, carrot, lemon-juice, milk, onion, orange-juice, peas, potato, turnip.

The addition of a suitable proportion of fresh lime or orange juice, fresh fruit, fresh vegetable, fresh meat or beef-tea made from it, or fresh milk will cure scurvy, or, where tinned foods are being chiefly consumed, tend to delay or altogether prevent its onset.

Foods which are rich in potash almost necessarily require an addition of common salt, so that, as has been already explained, the excess of potash may be quickly eliminated. Bunge's conception, therefore, that common salt tends to widen the circle of our food supply is doubtless correct.

An interesting contribution—fraught with suggestiveness—has been made to our knowledge of the metabolism of the mineral salts by Motteram, who by careful spectroscopic examination has ascertained that the potassium-content of the red blood corpuscles of cancerous patients is considerably higher than in health, the difference being represented by the figures 1.5 and 3. The sodium-content, on the other hand, showed no change. The sodium-content of all cancerous tumours is the same, whereas the potassium-content of primary is higher than that of secondary tumours.

A comparison between the composition of the ash of milk and that of the young animal reared upon it shows a wonderful agreement except in the case of human beings. This striking difference is explained by the statement that it is essential for animals which develop very rapidly after birth to be nourished by a milk corresponding closely to the chemical composition of their young, whereas this is not necessary in the slowly developing human offspring, because the various tissues are not built up so uniformly, nor are so many changes taking place when suckling ceases and other sources of nutriment are resorted to.

Lime Salts in Rickets.—A critical survey of the food of

young children is closely bound up with the chemical composition of milk, and it is now recognised that in the past too much stress has been laid upon its content merely of protein, fat, and carbohydrate, and too little upon the amount of inorganic substances associated with them. From this point of view the most important salt is lime, which is absolutely indispensable for the growth of bones and teeth, and it has been suggested that rickets is caused by a lack of lime salts in the nourishment. Part of the routine treatment of this disease consists in the exhibition of phosphate of lime, on the assumption that there is a deficiency of lime in the food or drink, and this conception was, no doubt, fostered as much by the fact that rickets appear most frequently when for any reason there is a cessation in the administration of mother's milk as because its point of attack is chiefly centred on the bony structures.

In most cases, however, other parts of the body, such as muscles and nerves, are involved, and the osseous changes are frequently of slight significance, and it is known that rickets sometimes appears with a food that is rich in lime, and even when mother's milk is the sole item of nutriment. One great difficulty in the investigation has been the lack of knowledge as to the precise method of combination in which the inorganic substances are present in the food, whether as inorganic salts or closely incorporated with the proteins. Lime, we know, is present in milk in quantities proportional to the citric-acid-content, but it is not believed that the lime is simply dissolved by this acid. In any case it is fairly certain that all the lime is brought into a state of solution in the intestine and most probably absorbed by the duodenum, and so is capable of being assimilated.

It must be assumed, therefore, that deficiency of lime in the food is not the causative factor of rickets, but that the power of assimilation for lime is lessened. For this reason, in the treatment of this disease it is of greater importance to improve the metabolic powers by any means at our disposal than to increase the supply of lime.

There are bodily conditions, indeed, in which it may be judicious to exclude as far as possible foods containing lime, although the daily normal requirement of a child is no more than one-third of a gram, and that of an adult only a little

over 1 gram. The view enunciated by dietists barely ten years ago, that it is exceedingly doubtful whether the intestine absorbs more mineral salts than the tissues require, has now been modified to the statement that the mineral matter of our food is absorbed in an excess far exceeding the physiological requirements of the body, but that the individual cells have a selective capacity enabling them to pick out from the mass presented to them the exact quantity essential for their perfect nutrition. Just how far this states the case with precision it is impossible at this time of day to say; but in the light of our knowledge of the occasional evil effects of an excess of chloride of sodium, it behoves us not to rest content simply when we have arranged for the provision of a supply of mineral salts which ordinarily suffices for nutrition.

Lime Salts in Metabolism.—Quantitative knowledge is important in view of the assertion that at least the salts of calcium have an enormous influence in metabolism, both in health and disease. The influence they exert on the formation of bone and teeth, on the coagulation of the blood and milk, on the setting of gelatine and on the "tone" of the cardiac muscle is now well known. Blair Bell states that "Lime salts are not only necessary for the construction of the body and its growth, but for keeping it healthy and in repair, and for the reproduction of the species." He affirms that the salts of lime only become pathological when they endeavour to rescue diseased structures and repair them. The deposits of lime salts in the atheromatous patches which occur in the subendothelial layer of the intima of blood-vessels, the calcification of tubercular patches, and the hardening in the neighbourhood of old wounds are well recognised. He declares that the calcium soaps found in appendicitis are results rather than the causes of the inflammation.

It is known that the fat in the food determines the nature of the fat in the tissues. The fats usually consumed, especially those of beef and mutton, containing as they do a minimum of olein, consist chiefly of saturated fatty acids, *i.e.*, those in which the capacity of the carbon chain for taking up the hydrogen has reached its limit. This factor again determines the nature of the soaps in the wall of the intestine

en route for excretion, and when they are calcium soaps of saturated fatty acids, some disease, such as mucous colitis or intestinal lithiasis, both clinically associated with appendicitis, is usually present. The fats utilised for the needs of the tissues are not neutral fats but complex phosphatides, their fatty acid radicles being largely unsaturated, and it is thus maintained by others that this indicates that the calcium, or saturated fatty acid radicle in the calcium soaps formed from butcher's meat, plays an important part in the causation of appendicitis.

Hans Meyer thinks that calcium salts have a sedative effect on the sympathetic nervous system, and diminish the permeability of the walls of the blood-vessels. When they are withdrawn from the system (as in oxalic acid poisoning), the result is an over-excitability of the whole visceral and cerebro-spinal motor nervous system.

Sir James Barr believes that the fixed lime salts, *i.e.*, those which are linked on to the molecules of albumin, increase the viscosity and coagulability of the blood, while the free calcium ions in association with the suprarenal and pituitary secretions increase the tone and contraction of the arteries and arterioles, heighten the blood-pressure, slow the pulse, and maintain the force and efficiency of the heart. Adrenal extract and pituitary secretion lead to the retention of lime salts in the blood and tissues, while the secretions of the thyroid, ovaries, and testes increase calcium metabolism, diminish the free and fixed lime in the blood, and thus lessen its viscosity.

He states that the lime salts deposit in any tissue which is not functioning properly, and he gives a list of diseases in the causation or treatment of which lime plays an important part. At the same time he indicates that if a man takes plenty of exercise he can easily get rid of every excess of lime in his body. The diseases which in his opinion have resulted from the ingestion of too much lime, or where its exclusion from the diet is indicated, are arterio-sclerosis, angina pectoris, asthma, acute rheumatism, locomotor ataxia, migraine, and colitis, and those which have arisen because the system is suffering from a lack of lime, or which would benefit by further administration of lime in the diet or as medicine, are pneumonia, epilepsy, disseminated sclerosis, neurasthenia, eczema,

muscular rheumatism, and "cramp" in the muscles. For the proper guidance of patients suffering from any of these maladies it is therefore judicious to possess a knowledge of the calcium contents of food.

Food-stuffs containing Calcium.—Food-stuffs containing lime salts may be classed in three groups: (1) Those which contain over 2 parts per 1,000, *e.g.*, eggs, cheese, cow's milk, green cabbage; (2) those which contain between 1 and 2 parts per 1,000, *e.g.*, peas, lentils, cauliflower, haricot beans; (3) those which contain less than 1 part per 1,000, *e.g.*, bread, meat, fish, potato, apples, pears, plums, &c. Loeper and Gouraud suggest that those who suffer from atheroma or in whom it may be impending should diminish their intake of foods containing lime salts and at the same time adopt means for increasing their elimination from the body. This should be effected by purgatives and diuretics, lime, as we know, being excreted by the bowels and kidneys. An average of 20 centigrams should appear every twenty-four hours in the urine, but an acalcic diet will reduce this by half, while the administration of milk will double, or even treble, the quantity.

Iodide of potassium in large doses is said to bring into solution all the salts of lime, even those fixed in bones. Its exhibition is consequently rather dangerous, because something untimely may occasion their precipitation in the soft tissues. Bicarbonate of sodium, on the other hand, has no power over the fixed lime salts, but aids in the solution and excretion of those in the soft tissues. An eminent American scientist told me that when his wife was threatened with blindness from increasing cataract, he put her upon a stringent acalcic and dechlorinated diet, with massage and manipulations in the cervical region, with the result that at the end of two years her vision had immensely improved, and practically all sign of cataract had disappeared.

Oxaluria and its Dietetic Treatment.—The excretion of lime by the kidneys is often, especially in those who metabolise purins badly, complicated by its combination with oxalic acid, and a well-recognised group of symptoms, including headache, backache, listlessness, depression, and sometimes dysuria, is often to be met with in such subjects. This

condition has been termed oxaluria, and it has been conjectured that food-stuffs containing oxalic acids are particularly to be blamed for its origin. Hence such foods as rhubarb, spinach, sorrel, tomatoes and strawberries, which are stated to contain large quantities of oxalic acid, are shunned by sufferers from this ailment, and even figs, plums, potatoes, beetroot, gooseberries, tea, coffee, and cocoa are placed upon the proscribed list by enthusiastic dietists.

But it has been demonstrated that it may owe its inception to other circumstances, such as fermentative dyspepsia, from an excess of carbohydrates in the diet, or at least from carbohydrate decomposition in the alimentary canal under conditions not yet clearly apprehended, and that even the acidity of the gastric juice has much to do with the absorption of oxalates from the food. General practitioners are well aware of the fact that subjects of hyperchlorhydria have an idiosyncrasy for excessively acid fruits and vegetables, and that acids of all kinds are apt to disagree with them, while alkalis suit them, or in any case give them temporary comfort. For those who refuse to deny themselves the pleasure of eating stewed rhubarb, even where experience has taught them that its ingestion is almost immediately followed by an effusion into the joints, it may be comforting to know that if it be soaked for two hours prior to cooking in a solution of carbonate of soda, this water discarded, and then a very large pinch of bicarbonate of soda be added to the water in which it is cooked, immunity from the usual disastrous consequences may be expected.

The appearance of oxalate of calcium in the urine is not sufficient reason for diagnosing oxaluria, because it is a constant constituent of human urine, although it may not always deposit in crystalline form. It is only when an excessive quantity is present in the urine that the designation oxaluria is correctly applied, and in such circumstances inquiry must be instituted to discover whether its origin be exogenous, *i.e.*, produced from the food introduced into the alimentary canal, or endogenous, *i.e.*, due to some metabolic disturbance. Very little, however, is known about the method of its endogenous production, but it is always important to note whether crystals of oxalate of calcium are present in newly passed urine, or

whether they deposit after it has been passed. Klemperer and Tritschler have demonstrated that the acid phosphates of calcium, sodium, and magnesium—especially the last, and also other salts of magnesium, such as the sulphate—exercise a solvent action on calcium oxalate.

The treatment of oxaluria, with the object of preventing the formation of concretions or dissolving those already formed, resolves itself into (1) diminution of the excretion of oxalic acid; (2) increasing the solubility of oxalate of lime in the urine. The former indication is met by expunging from the dietetic list all articles containing oxalic acid, such as tea, rhubarb, sorrel, spinach, and the avoidance of gelatine, which undoubtedly increases its output. Milk, white of egg, and all fats except yolk of egg should likewise be avoided. Acidity in the alimentary canal should also be diminished to prevent as far as possible absorption.

To fulfil the second indication, foods containing magnesium, such as rice, peas, farinaceous foods, and coffee, should be substituted; small doses of sulphate of magnesium should be exhibited, so that magnesia may be in excess in the urine; and citrate of potash not only prevents the formation of oxalate of lime crystals, but acts as a diuretic and so increases the volume of fluid available for solution. Acting on Klemperer's hint, acid phosphate of soda has more recently been recommended as a solvent.

It is probably futile to attempt the adoption of an acalcic diet in oxaluria, for no diet can be planned that would reduce the calcium-content so low as to be insufficient to combine with the few centigrams of oxalic acid excreted daily. Even in cases where enormous quantities of oxalate of calcium crystals are excreted in the urine, as amongst the Manipuris of Eastern Bengal, whose diet is entirely confined to vegetables and fruit, and whose drinking water is prominently deficient in calcium salts, it is quite evident that excess of calcium is not necessary for the formation of the oxalate of lime. Some other factor is always in operation, and therefore, in addition to the measures already suggested, the rational treatment consists in improving the metabolism of carbohydrates so as to inhibit the formation of endogenous oxalic acid.

The salts of magnesium, fluorine, iodine, or sulphur, although

doubtless important constituents of the body, are not of special significance in relation to any dietetic system.

Phosphorus and its Salts.—Phosphorus is present in varying proportions in food—meat, milk, eggs, cheese, and animal foods generally being richer in this ingredient than vegetable foods. Except, however, in young growing animals it is hardly possible to conceive of there being a deficiency of this substance in any reasonable mixed diet. A deposit of phosphorus in the urine is not of infrequent occurrence in quite ordinary circumstances, but it is only when urine heavily laden with calcium and magnesium phosphates issues in a turbid milky condition from the bladder that the term “phosphaturia” is requisitioned to describe it. This does not necessarily indicate either an active increase of these substances in the urine or the existence of any morbid process whatever, but is dependent either upon a relative increase of the alkalis or a relative decrease of acids in the urine.

The most common occasion for the appearance of such a deposition of phosphates is a diminution in the acidity of the urine, due to a diet rich in alkaline carbonates, or one containing alkaline salts of vegetable acids or alkaline albuminates, because these yield alkaline carbonates after being consumed in the body. This results in a transformation of the soluble diacid phosphates into insoluble monacid or insoluble normal phosphates. A temporary retention of acid in the body, as after a meal especially rich in protein, is often followed in two or three hours by excretion of insoluble phosphates, simply because there is for the nonce a relative increase of the alkali in the urine. The condition is hence sometimes termed anaciduria, and it is to be observed likewise after the body sustains a distinct loss of acid, *e.g.*, from vomiting, especially in hyperchlorhydria or after repeated washing out of the stomach.

To effect a disappearance of the phosphatic urinary deposit, it is not always necessary to resort to the exhibition of acids, but it is much wiser, especially in neurasthenic cases, to enjoin hygienic and tonic treatment. When, as is sometimes the case, an acid is indicated, then, as Hutchison has shown, the preference should be given to acid sodium phosphate.

A special form of phosphaturia, associated with excess of

lime in the urine and a corresponding diminution of calcium in the faeces, has been described in children, and owes its existence to an alteration in the secretion of the mucous membrane of the large intestine, usually referred to colitis. It is practically the only form really amenable to dietetic treatment, the deposit quickly disappearing after the substitution of an acalcic diet for one rich in lime. Excess of phosphorus pentoxide over calcium in the food is stated to be the cause of a very prevalent bone disease amongst the horses, mules, and donkeys of South Africa, for when the oat-hay and maize, which show a preponderance of the acid compound over the basic one, and which constitute the ordinary diet of these animals, are supplemented by lucerne or other leguminous fodder, rich in lime, the disease rapidly disappears.

Joulie asserts that the blood is an acid fluid because it retains in solution calcium and magnesium phosphate, both of which are precipitated in alkaline or even feebly acid solutions. He has evolved a process for estimating—what he terms—the “physiological” acidity of the urine, which he considers an index to the acidity of the blood. By comparing this with the P_2O_5 content of the urine he obtains data which enable him to state whether hypophosphatia or hyperphosphatia exists, a valuable indication for treatment.

A considerable amount of evidence has been advanced in recent years in support of the belief that beri-beri—a disease the outstanding characteristic of which is multiple peripheral neuritis—really owes its origin to a deficiency of the organic compounds of phosphorus. It has long been known that tropical beri-beri occurs with great frequency in certain Eastern races where the staple diet is rice, and in a general way the incidence of the disease has been associated with polished rice, from which the outer layers, including the pericarp, had been removed in milling. Ship beri-beri arises among the European crews of sailing ships who have been deprived for long periods of fresh food, and have been compelled to live on dry food, especially peas and beans, which could only be softened by prolonged boiling in soda, and pickled meat so old that it had parted with much of its organic phosphorus.

It has been conclusively demonstrated by Schaumann

amongst others that rice capable of inducing tropical or ship beri-beri would also produce polyneuritis in fowls which were fed exclusively upon it, and that even barley and white wheat flour, in which the outer layers of the grains have been removed in milling, and in which consequently the proportion of phosphorus is very low, could induce the same disease. Identical results were produced by removal of the organic phosphorus from food-stuffs by the action of the solvents or its destruction by a high temperature.

Now, while the addition of inorganic or organic phosphates in no way nullifies the deleterious action of the defective food-stuff, it is a fact of pregnant import that substances rich in organic compounds of phosphorus, such as pancreas, peas or beans, yeast, testicular extracts, or wheat bran and rice meal—the parts of the rice and wheat removed in milling—are by being added to the food capable of preventing the development of the disease in animals or curing it when present. It is essential, however, that these articles should be used to supplement the food in sufficient quantities to supply at least 2 grams of phosphorus per day, that being the minimum amount required for an adult. It is also known that oatmeal, rye bread, whole rice (paddy), and barley, all of which contain organic compounds of phosphorus in varying degree, are incapable of setting up polyneuritis in pigeons, and that beri-beri does not occur when rice containing a sufficiency of P_2O_5 , "cured rice," is used.

Eddie and Simpson, who subjected the matter to the test of experiment, have published their results, so far at least as they relate to wheat. They found that adult pigeons fed exclusively on unadulterated and unbleached white wheat bread rapidly developed polyneuritis and died on the average on the twenty-ninth day. They rapidly revived, however, on the addition of yeast to the diet, provided this was not delayed too long, and on an exclusive diet of whole-meal or standard bread, which contains 80 per cent. of the wheat berry, they maintained proper health.

It is evident therefore that the organic compounds of phosphorus are absolutely essential to the health and well-being of man, and that he is unable to manufacture his own organic compounds of phosphorus from inorganic phosphorus.

It is even probable that a daily supply of the different compounds of organic phosphorus is necessary, as no proof exists to show that nucleins, lecithins, phosphatides, phytins, or other varieties, are capable of being substitutes the one for the other.

Iron.—The quantity of iron contained in a man weighing 70 kilograms is calculated to be about 3·2 grams, and something like 7 to 8 milligrams are excreted daily by the intestine during fasting experiments on man. We may take it, therefore, that a diet containing 10 milligrams of iron should suffice to provide the daily requirements of the body for that substance, and this is the average content of an ordinary mixed diet. It is especially abundant in foods such as beef and yolk of egg, while a litre of milk only contains about 2·3 milligrams of iron, so that were the diet restricted to milk alone, quite 4 litres would be required to supply the necessary quantity of iron. The amount of iron in the body of a newly-born rabbit is greatest at the time of birth, and gradually decreases, until towards the end of lactation it is at a minimum, but the store is quickly replenished as soon as food richer in iron begins to be taken. An analogous state of affairs exists in the infant, and hence it is unwise to restrict the human offspring to a milk diet for a longer time than the eight or nine months of the ordinary period of lactation. In health, it is sufficient to provide the body with the amount of organic iron contained in an ordinary mixed diet to maintain the supply in a normal state of efficiency for the purposes of the organism, but whenever any marked deficiency of iron exists in the blood, then it is requisite to administer medicines either containing iron or other substance capable of stimulating the blood-forming organs to greater activity. This is necessary because there is no food with an iron-content sufficiently large to cause the disappearance of anæmia.

The ratio of sodium, chlorine, iron, and calcium to potassium and phosphoric acid required by animals is far higher than exists in most plants. This is well exemplified by the appearance of "bran rachitis" amongst horses fed largely on bran, the ash of which contains 3 per cent. of phosphorus pentoxide and only ·2 per cent. of lime, and which is, therefore, unsuitable as a bone-forming food, despite a widespread belief to the contrary.

Deficiency of the Mineral Salts.—It will hardly occasion surprise, after what has been said regarding the importance to the body of an adequate supply of mineral salts, that a theory has been enunciated insisting that the cause of all diseases is lack of a sufficiency of saline material in the system. It was originated by Lahmann, who contended that the composition of the blood, both as regards its specific gravity and its corpuscular element, is liable to very great variation. He therefore believed that the blood is the principal medium of inducing predisposition to disease. He affirmed that, as it is formed from food and drink, it is of paramount importance to measure with accuracy the constituents of our daily diet. In his opinion far too much attention is concentrated upon the chemistry of proteins and far too little upon the mineral substances. He drew attention to the fact that plants refused to thrive if the soil be exhausted of its mineral substances, and that dogs and other animals fed upon washed meat, pure starches, fats, and sugar—*i.e.*, food deprived of its saline matters—die after a short time. They would also die even although we added to this diet the inorganic salts of milk in precisely the same proportions as they are to be found in the ash of milk. Yet animals fed exclusively on cow's milk will go on living indefinitely.

He referred to Bunge's question whether it was possible for the inorganic salts of the milk to be in chemical combination with its organic substances and only capable of digestion in this combination. His rejoinder to this was that the citrates of potash, magnesium, and calcium in cow's milk are not inorganic, but organic or organised salts, and as such subject to the same metabolic changes as the tissues, and it is, therefore, impossible to replace them by chemical salts. He repeated the observation that a food mixture may have precisely similar amounts of proteins, fats, and carbohydrates to another food mixture and yet differ very considerably with regard to the proportion of inorganic substance. He was satisfied that the total amount of food salts contained in the ordinary diet of European nations is not only altogether too small, but the relative proportions of food salts to each other also differ widely from what he categorised as the standard food mixture. He insisted that it is not sufficient to say that the body

requires $3\frac{1}{2}$ grams of salts or inorganic substances daily. It is essential to specify how much potash, soda, lime, iron, &c., is required in a well-balanced ration. As there is usually a deficiency of salts in the diet, he suggested that this can be adjusted by adding root and leaf vegetables, salads, and fruits to the ordinary food. In particular he claimed that the quantities of soda and lime in the daily diet are far below the quantities necessary to maintain a healthy existence, whereas the quantities of potash, iron, and phosphoric acid are generally too big. He quite frankly ascribed the prevalence of rickets and bad teeth to the ill-proportioned combination of salts.

Again he contended that anæmia has nothing to do with a want of iron in the blood, because practically any food mixture contains an abundance of iron. The bones and teeth decay because there are too many acids and salts in our food in proportion to the amount of base, hence, not being neutralised, they easily dissolve the osseous substance of the body. He was also an advocate of the theory that in meat quite one-half of the constituents, including, of course, the albumin and food salts, are as good as useless, their molecules being deprived of vitality because, having performed their work in the body of the animal when alive, they are only waiting to be excreted. In vegetables, on the other hand, he declared, these same molecules perform no work, and hence are abounding in vitality. Just what difference he was able to discover in the metabolism of the tissue-cells of an animal capable of locomotion and a plant condemned to a stationary existence he did not presume to say. He considered the addition of chloride of sodium to be unnecessary if we choose our food correctly. It is a stimulant and, like all stimulants, conduces to intemperance. Rice, he insisted, supplies us with too few salts and potatoes with too many, because they compel us to force through the kidneys more than forty times the amount of alkaline salts that rice does, much to the detriment of both stomach and kidneys.

To obviate this defective provision of our food, he supplied a food salt extractive prepared from leaf vegetables, but the experience of those who have placed themselves under his treatment has not convinced me that any notable addition has been made to the practice of scientific dietetics. If he has

demonstrated anything at all it is that we should not be content with too restricted a dietary, but our choice should range over a great variety of comestibles suited to the particular season in question.

Moreover, there appears to be nothing very novel either in his theory or his practice, nor can they be said even to have the merit of originality. After his remarks on flesh foods it is to be inferred that he either was a vegetarian or favoured that cult, and Bunge not only points out the necessity for the addition of common salt to such a diet, but was able to procure a sample of a salt obtained by ignition of a plant and used as a seasoning for their vegetarian diet by the negroes near Khartoum. On analysis this salt was proved to contain 19.27 Na_2O and 4.92 per cent. K_2O .

In lieu of fresh vegetables it is now possible to obtain dried and pulverised specimens of spinach, celery, lentils, &c., so that large quantities of natural mineral salts can be prescribed in an agreeable form; but introduced as they have been by vegetarians, we question whether it might not be fair to retort that their molecules are deprived of all vitality in a manner similar to the flesh of animals.

Mineralised Dietetic Agencies.—Mineral salts are freely administered in medicine, both for their local and constitutional effects, for quite other than dietetic purposes. We are familiar with the action of alkalis and acids, with the use of chloride of calcium and citrate of sodium, the former to encourage and the latter to discourage the tendency of blood to coagulate; with the exhibition of phosphorus, iron, hypophosphites, glycerophosphates. We are becoming daily more suspicious of the claims of any of these substances to take their position as constituents of the tissues, however much we may recognise their capacity for stimulating functional activity. We are not convinced that so-called organic preparations of chemical salts have a greater capability for action than the inorganic preparations of the same salts when these latter can be tolerated.

It has been proved, indeed, that at any rate in the case of silver, bromine, and iodine salts their effective capacity is determined by the actual amount of the element contained in them, which is always much less than in the inorganic preparation, and that the only advantageous point associated

with their administration is due to this very fact—a less vigorous but less irritating result being provided because of the distinctly diminished content of the elemental substance.

In these latter days, however, we are threatened with a whole deluge of organic preparations of the glycerophosphates, iron, iodine, bromine, &c., mostly with a protein basis obtained from milk, meat, or wheat, and all sorts of claims are made for their superiority, their excellence, and their wonderful recuperative, revivifying, or regenerative properties. We are even compelled to recognise preparations of a much less innocent character with alcohol as their basis, the continued use of which is necessarily potent for evil of a serious nature. After much experimentation with such preparations I am not satisfied that their proprietors have substantiated the claims made for them.

The best that can be said in any case for most of them is that those who have a difficulty in assimilating inorganic preparations have a weaker dose of the drug presented to them, generally in a less disagreeable form, and because of diminished disturbance of the organs of digestion there is at least a chance of a greater quantity of the salt being absorbed. Exceptions may probably at times require to be made in favour of one or other proprietary substance, and if it be not invidious to mention one by name, I have seen the administration of liquid iron somatose followed by the most remarkable improvement in cases of anæmia after complete failure with the most approved preparations.

One claim which is continually being made for those with a milk protein basis is that the casein is metabolised and utilised in much greater quantity than is normally possible. But no evidence has ever been offered in support of this statement, and I am not satisfied that the chemical salt combined with it acts differently to what it would have done in an ordinary pharmaceutical preparation. I am quite certain that such substances lend themselves to unintelligent dosing with potent remedies, and I have seen evidence many times that they are responsible for the inception of neuritis, nasal catarrhs, and many other maladies, which the unfortunate victims rarely ascribe to their proper source. The enormous prevalence of neuritis to-day as compared with even a dozen years

ago should make us pause to reflect on such a possible causation.

It is fair to add that these remarks have significance only in connection with preparations which are avowedly manufactured with the addition of chemical salts, and that there exist many meat extracts and dried milk products in which the mineral salts are present in the same organic combination as in meat or milk itself. But even here economy should be practised in the eulogistic language employed by their proprietors, and caution must be exercised in prescribing them in more than dietetic doses with the object of adding to the strength of patients. In the great majority of cases disappointment in this connection is sure to result, because it is not easy to make the body richer in albumin merely by increasing the amount of albumin given.

Perhaps the most important lesson to be learned from calm reflection on the facts mentioned in this chapter is the necessity for constant variation in the diet. The average man excretes some 23 grams of mineral salts daily, quite the half of which he must derive from the food he eats, and it is even judicious of him to depend for the most part on the same source for his supply of chloride of sodium, which constitutes the greater portion of the other half. Now as 70 per cent. of the dietetic mineral salts are scattered over the various food-stuffs of the vegetable kingdom, it is essential that from day to day different sorts of fruits and vegetables containing the necessary salts should be included in the menu, and these should be changed from time to time according to the season of the year. This not only insures a regular supply of all the mineral matter requisite for nutrition, but provides it in such a form that it is easily assimilated and incorporated with the tissues. It is apparently also a matter of great moment that food-stuffs should not suffer too much interference in their preparation for the table, as in this way they are apt to be robbed of many of their valuable qualities. It has been amply demonstrated that continuous deprivation of the organic mineral salts of food is detrimental to the maintenance of good health and directly provocative of disease.

CHAPTER VIII

DIETETIC THEORIES ASSOCIATED WITH WATER

WE have already carefully considered the important part played by water in metabolism, and have indicated the necessity of a sufficient supply thereof to subserve the nutritional functions of the economy. We are sufficiently familiar with the "water cure" to know in a general way that the annual pilgrimage which so many patients undertake to a home or foreign spa is mainly for the purpose of "washing" something out of their tissues. That the physicians of the early part of the eighteenth-century were already well acquainted with some similar process is evident from the vegetarian Dr. Sangrado's advice to Gil Blas, who was inclined to plead ignorance of therapeutics. "You need not waste your time in studying the nonsense written by other doctors. You have only to follow my method. Never give a patient medicine. Bleed him well, and tell him to drink a pint of hot water every half-hour. If that does not cure him, well—it's time he died."

Whatever other treatment be adopted, and whatever other factors may be in operation, it is usually held to be essential to consume a sufficient amount of water during the "cure," although in some spas this quantity is by no means distinguished by its magnitude. As there is usually—though not always—some ingredient in solution in the water, there is an inclination to attribute the beneficial influence derived from residence at a spa to this substance, although its amount may be so insignificant that chemists have great difficulty in isolating it, and even sceptical local doctors are

inclined to ascribe the effect to some occult dynamism resident in the water itself. I have little hesitation in saying that quite an appreciable portion of the benefit derived from spa treatment must be assigned to the influence of pure water employed both externally and internally in unaccustomed quantity and manner.

WATER AS A THERAPEUTIC AGENT

Winternitz states that "when it is desired to flood the tissues with fluid, to increase the weight of the blood column, to augment the tension in the vascular system, to increase the capillary pressure, water should be administered in small single doses, but repeated at short intervals of from twenty to thirty minutes throughout a considerable period of time. When, however, it is desired to cause disappearance of fluid effusions and to stimulate absorptive power, it will be possible—however paradoxical it may seem—to effect this by the drinking of cold water, if we alternate the administration of fluid with considerable intervals of absence from all drink." He thinks that in this way the blood becomes more thickened, so to speak, and therefore better able to absorb fluid from the tissues, and to initiate absorption and elimination. For this purpose he recommends somewhat larger quantities of fluid every six or eight hours, and the withholding of all fluids in the interval. When once absorption is initiated, it encroaches on the tissues as well as the fluids of the body, so that there is brought about an increase of waste and destructive metamorphosis or katabolism.

A supply of water slightly above the normal, with an equivalent increase in the consumption of food, induces a gain in body-weight, indicating that anabolism has been stimulated, but an excessive consumption of water is followed by a diminution of body-weight. The effect of an increased supply of water is soon displayed by a corresponding activity of the kidneys, not only as far as regards the excretion of water but also of urea, and this is accompanied by a lessened output of uric acid and oxalic acid, in cases where the latter has previously been present. There is likewise a proportionate increase in the phosphates and sulphates of the urine,

while oxygen is consumed and carbonic acid eliminated in great quantities by the lungs.

The Schroth Treatment.—These results are, of course, significant of increased metabolism, and, as such, can only partially be reconciled with the unquestionably beneficial therapeutical results derived from the Schroth treatment. The underlying conception of this method of dietotherapy, devised by a simple peasant and placed upon a scientific basis by Cantani, a celebrated Italian physician, is the increased combustion of the tissues induced by intense restriction of water-drinking. At the same time the consumption of food, especially of fats and proteins, is diminished almost to vanishing point, because the sole item of the menu is dry rolls, of which the patient is allowed to eat as many as his deficient appetite demands. After the absolute deprivation of liquid of any sort for two or three days, a drinking day is permitted, but this is limited to a little—say a pint and a half of light white wine, preferably good unadulterated Rhine wine or Moselle. The wine should, however, not be drunk cold, but slightly warmed, although in the summer months it is permissible after drinking the first two glasses warm to finish the rest cold. As the acidity of the wine becomes more apparent after warming, a very little sugar may be added. The whole must not be drunk at one sitting, but consumed in small quantities by sipping it at intervals throughout the day. After this “drinking” day two or three “thirst” days must ensue, and during all this time the patient is allowed to eat as many stale rolls as he desires. If the thirst becomes absolutely unbearable, not more than one wineglassful per day of oatmeal gruel mixed with sugar and lemon-juice is permitted, and this heroic restriction of liquids is maintained for many weeks.

The final factor in the regimen consists in the application of moist packs every evening, and it is claimed by Schroth that by this means a certain quantity of fluid is, by cutaneous absorption, supplied to the tissues without in any way disturbing the alimentary functions. Jürgensen, however, who has experimented carefully with the system, and who is responsible for the addition of the libation of wine as described above, has disproved this assertion and demonstrated

conclusively that no liquids are absorbed by the intact skin.

This treatment has been carefully studied by Dr. Sandoz, who has utilised the researches and experiences of Landauer, Dennig, and others, and the results of his investigations are as follows: In the first place only from 300 to 500 c.c. of urine are eliminated daily in a subject taking 500 c.c. as a beverage, and about 300 c.c. in his food, although a great deal more may be excreted by the obese. This is accounted for by the fact that the diet is a dechlorinated one, and, as in the obese there is practically always a retention of chlorides, the suppression of the chlorides in the food liberates the oedema liquids present in the tissues. It is noteworthy that the urinary secretion increases or tends to increase during the dry days, despite the diminution, or at least restriction, of the amount of fluid taken. The water excreted by the skin and lungs, more especially in the case of the former, is much diminished. The body-weight is greatly lessened, as much as 7 to 10 pounds being lost in a week, and a five days' dry regimen in dogs has sufficed to reduce the weight of muscle tissue by 75 per cent. There is a decided daily increase in nitrogenous metabolism, a greater proportionate amount of nitrogen being eliminated during the "dry" period than during the administration of liquids.

As the food was chiefly carbohydrate containing a very limited quantity of protein, and almost no fat, and as the appetite was extremely limited, not more than five or six rolls of 1,000-1,200 calories food value were consumed daily. The balance required was mainly provided by the tissues, and hence histolysis was present to a considerable degree. As a rule, however, much less food, say two or three rolls of 400 to 600 calories value, was required, and so the resulting destruction of albumins was intensified.

The periodical use of wine not only increased the excretion of water, and with it of urinary nitrogen, but by dilating the cutaneous capillaries favoured the loss of heat, and thus to maintain the body heat a further combustion of the tissues became necessary. The wet packs were alternately cold and hot, the former extracting more heat from the body, whilst the latter, by encouraging the rise of temperature, determined still further destruction of tissue poisons.

The curative results of this treatment in cases of rheumatism are stated to be almost incredible, and especially notable is the swift disappearance of all pain. The urine becomes extremely dark and high coloured, with a thick uratic deposit, and adverse critics of this mode of treatment declare that this is simply due to high concentration from the exclusion of moisture from the system, but this view is contradicted by the fact that if the cure be persisted in the urine gradually assumes a lighter colour, and eventually becomes quite clear pale yellow, or "straw" colour. In support of the view that there is increased tissue combustion, especially on the drinking days, the sediment of the urine is much increased directly after these days, as compared with the thirst days.

The advocates of this system claim that it is capable of working apparent miracles in cases otherwise incurable amongst them being rickets and its sequelæ, crooked spine and limbs, gout, hæmorrhoids, varices, hypochondria, chronic cutaneous disorders, fistulæ of all kinds, and even stricture of the urethra. The thirst, which is at first almost unbearable, subsequently diminishes, and is somewhat relieved by the cold compresses. Appetite, which in the early days practically vanishes, gradually improves, and this is encouraged by the increasing moisture and cleansing of the tongue. This is a point worthy of emphasis, that, contrary to expectation, all cures characterised by dietetic restrictions are attended by a dry, thickly-furred tongue, but as the cure proceeds it is claimed that the tongue becomes moist and finally presents a uniform healthy red colour.

On the other hand von Noorden reports that "some of the cases developed signs of scurvy, and a few of them died."

Cantani's Views.—Cantani, who employed this treatment with great success in gout, rheumatism, gravel, diabetes, &c., contended, in opposition to those who maintain that uric acid is formed in the kidney, that it developed in every tissue without exception throughout the body. The kidneys, of course, produce a certain amount of uric acid proportionate to their size, in common with all the other tissues, but they do not form it as a rule in their secreting cells. He asserts that while in the healthy individual uric acid is chiefly formed in the kidneys, in the unhealthy, whose blood is charged with

large amounts of uric acid, it likewise develops in almost all the organs of the body. Its development depends upon the fact that more nutritive matter is received than can be utilised, and whenever this takes place uric acid is formed. In other words, he supports the view that instead of metabolism proceeding to its fullest extent of urea formation, it stops short at uric acid. This, being absorbed into the blood, is then deposited wherever there is local irritation in joints or elsewhere. In contradistinction to Haig, who avers that uric acid is chiefly introduced in the food and must be excreted directly by the kidneys, Cantani considers it as an anomalous metabolic product of the nitrogenous foods and tissues, and that it is possible by increased metabolism, consequent upon a fresh supply of oxygen, to burn it up into urea, and so have it excreted.

Manifestly Cantani's exposition of the physiological action of the Schroth "roll cure" was purely an incursion into the realm of theory, as we know that the metabolism of uric acid proceeds along well-defined lines of its own, and whatever its relations with urea may be, they are not nearly of such an essentially intimate character as he has suggested. The explanation of any beneficial results of a dry diet cannot be a question of oxidation solely, because, although there is an increased disintegration of tissue protein, this is effected by hydrolysis, and so, as might have been anticipated, Salomon has proved clearly and decisively that there is never an increased consumption of oxygen during a period of thirst.

Reduction of blood quantity and blood-pressure will, however, mean relief to the heart, and the blood being hypotonic, an absorption of fluid, presumably laden with toxic matters, will take place from the tissues. Jürgensen has shown that the specific gravity of the blood serum rises as high as six parts in a thousand, and in Dennig's observation on a thirst case the residue left after drying the blood serum was over 1 per cent. greater after the cure than before, showing a loss of quite 13 per cent. of its water. Both the red cell count and the proportion of hæmoglobin rose appreciably in this case. In experiments upon a dog, Straub demonstrated that the normal muscular tissue after five days' thirst lost over a quarter of its fluid contents, and as it is

known that pigeons die when they lose 22 per cent. of the water in their bodies, it is easy to realise what an extremely dangerous procedure a severe thirst cure may be.

There is an undoubted rise in the excretion of nitrogen during a thirst cure, which has been proved to be due to an increased decomposition of protein. The marked increase in the excretion of nitrogen during a thirst cure is an indication of the autolysis of the tissues which we know to take place, and doubtless accounts for the feverish condition present, the temperature in some cases rising as high as 104° F.

In its original form the treatment has had practically no vogue in this country, and hence we are dependent for information as to its results—beneficial or otherwise—on reports from the Continent, many of which are from lay practitioners. We may consider it, however, as a fairly powerful plea for the adoption of moderation in diet, although its mode of action is rather clumsy and not altogether free from danger. One is rather relieved to find that patients undergoing the treatment are recommended not to engage in hard work, strenuous exercise, or fatiguing walks, a counsel of safety in strong contrast with the heroic exertions chronicled of those who embark upon the still more severe restrictions practised in the fasting system. Patients are also enjoined under no circumstances to take milk, which produces acid fermentation, and, according to Cantani, may jeopardise health or even produce rheumatism. It is a little surprising that the expectorations of the patient should be so astonishingly copious. They are at first thick, tough, gelatinous—evidently inspissated mucus—but later on become muco-purulent, yellowish green, pus-like, malodorous, and not infrequently accompanied by nausea. Whether this be due to an infective process producing bronchitis, which may be the explanation of the high temperature, or the result of the latter, is not apparent.

As we should expect, in common with fasting cases, there is considerable perturbation in the colon, the stool being suppressed for days or even weeks, and then a hard motion covered with mucus and blood being evacuated with much discomfort. This exaggerated constipation often alternates with diarrhoea, when copious evacuations of offensive fæces

and mucus with much "blood and matter" are reported to occur, and this corresponds with our knowledge of muco-membranous colitis, a disease largely dependent upon constipation.

Rational Drink Restriction.—Although English physicians lack experience in the intensely restrictive measures advocated by Schroth, they are well acquainted with the utility of the reduction in the amount of fluids for the cure of many diseased conditions. Doubtless the practice has been adopted in most cases more from a common-sense point of view than from any clear conception of the physiological principles involved, and for this reason has been, after a period of experimentation, discarded, or in any case decidedly modified.

Tufnel's Diet.—The best example of intense limitation of the ingesta is that associated with Tufnel's name, and employed in the treatment of aneurism under the mistaken notion that it tended to increase the coagulation of the blood. His prescription runs thus: Breakfast—2 ounces of bread and butter, 2 ounces of milk. Dinner—2 or 3 ounces of bread and butter with the same quantity of meat, and 2 to 4 ounces of milk or claret. Supper—2 ounces of bread and 2 ounces of milk.

No one to-day would dream of insisting upon such an attenuated diet list, for, apart from the fact that it is now known that restriction of diet lessens the coagulability of the blood, it is positive cruelty to make such harassing demands on the self-control and fortitude of the victim of such a deadly ailment—for be it noted that it is only in inoperable cases that such a menu would be prescribed. Complete abstinence from stimulating foods and drinks, and the limitation of the meals to the lowest point consistent with removing the pangs of hunger and thirst, are all that can be reasonably expected of any subject of aneurism.

Dry Diet in Dilated Stomach.—Cases of gastrectasis and atonic dilatation of the stomach form a more legitimate field for the employment of a dry diet. Whenever the musculature of the stomach is weakened, the greater curvature is stretched to a point considerably below the level of the pylorus, and ingesta of an innutritious character act only as an incubus,

and prevent the speedy evacuation of the gastric contents. Four small meals of highly nourishing solid food, most carefully masticated and without any admixture of sloppy food or liquids in any form, answer the requirements of most cases of the kind mentioned. Quite a usual practice amongst vegetarians in cases of dilated stomach is to prescribe only two meals per day, one at 8 a.m. and the other about 3 p.m., and I have examined several cases which were stated to have been cured by this method.

Drinking at Meal Times.—The vexed question as to the advisability of drinking fluids at meal times is one which amateur dietetic reformers invariably answer in the negative. At first sight this course of action is apparently justifiable, because we have already seen that practically no fluids are absorbed by the stomach wall, but are rapidly ejected into the duodenum in advance of the solid food. In a healthy individual this is likely to have no deleterious action on the process of digestion, but the stomach of the average town-dweller is not provided with a very strong musculature, and so the fluids are retained too long, diluting the digestive juices, delaying digestion, and favouring an increase of microbic putrefaction. Hence the average City man has solved this question for himself by limiting his consumption of fluids at meal times, especially at such meals where he is unable to rest in a reclining posture. For this reason his midday meal is usually restricted to a small snack, and he imbibes his fluids in the shape of weak tea in the afternoon and at his more leisured evening meal.

From the results of an experiment on the metabolic influence of copious water-drinking with meals, it would appear that in those cases in which the stomach can sufficiently deal with the increase of fluid, decided advantages accrue from its consumption. The subject of the experiment was a young man weighing 71 kilograms, who was placed on a uniform diet capable of maintaining him in a condition of "nitrogen equilibrium." For six days 900 c.c. of water were ingested daily, one-third of this amount being taken with the meals, and then for five days more 1,000 c.c. of water were added, and equally distributed over the various meals. At the end of this time the fluid was

again diminished to the original amount for a further period of eight days.

As might have been anticipated, several facts previously known, such as an increase in the body-weight and an increased excretion of urinary nitrogen, doubtless due to a "washing out" of the tissues, were corroborated. One would hardly have expected, however, to find a decreased excretion of fæces and fæcal nitrogen, nor a decrease in the quantity of bacteria excreted daily, although the two facts are distinctly correlated. The output of ammonia was increased, which was interpreted to indicate an increased excretion of gastric juice, and doubtless was the determining factor in the more economical utilisation of the protein constituents of the food. There was a decreased excretion of creatinin and a coincident appearance of creatin in the urine, and it is suggested that this indicated a stimulation of the protein katabolism by the copious water-drinking.

As it is quite exceptional for creatin to be present in the urine without the existence of some pathological process, its appearance is explained by the statement that the water had caused a "partial muscular disintegration, resulting in the release of creatin, but not profound enough to yield the total nitrogen-content of the muscle. The output of creatin is therefore out of all proportion to the increase in the excretion of total nitrogen."

Haas has shown in experiments on man that there are two well marked curves of nitrogen elimination after a breakfast of milk, bread, butter and cheese: one in the second hour, due to the washing out of nitrogenous end-products in the tissues by the early absorption of liquids swallowed at the meal, the other in the fifth hour, due to the absorption of food protein. If the tissues have been depleted of their urea by tea-drinking prior to such a meal, the primary curve is much lower, and the total elimination of nitrogen decidedly diminished.

From the findings above detailed it is concluded that many desirable features attend the consumption of a large amount of water with meals, and no valid reason exists as a contraindication to its use. In all probability the only objection which can be advanced in opposition to this statement is the

very cogent one that the habit of drinking largely at meal times is almost always accompanied by a tendency to bolt the food without careful mastication, and even in strong young subjects a continuance of this reprehensible practice must eventually induce a condition of dyspepsia incompatible with the existence of a powerful musculature in the stomach. Without advocating the exclusion of all fluids at meal times, it is injudicious to recommend more than a very modest consumption, leaving the greater quantity to be partaken of between meals, or first thing in the morning and last thing in the evening.

The moderate drinking of fluids during or shortly after meals is especially indicated in cases of pyloro-spasm, either due to hyperchlorhydria or excessive organic acidity, thus preventing undue distension of the stomach wall. In the former case, non-effervescent alkaline table-waters are most suitable, while in the latter, where hypochlorhydria usually exists, plain water, by simply diluting the hyper-acid contents, allays the spasm and enables the stomach to be more easily emptied.

Dry Diet in Heart Disease.—The treatment of cardiovascular disorders by a thirst cure was well known in the Middle Ages, but had fallen into desuetude until it was revived by Oertel a quarter of a century ago. His contention that in cases of failing compensation there exists a condition of "hydræmic plethora" was evidently advanced without sufficient authority, for subsequent observers have failed to verify it, or even to find hydræmia, unless where such a complication as malnutrition or inanition was present. All that is known is that in cases of insufficient cardiac action there is a reversal of the normal blood distribution, the veins containing more and the arteries less than normal. But such statements hardly affect the situation, because it is proved by actual practice that limitation of the ingestion of liquids is of great value in cases of all kinds where the cardiac muscle is labouring at a disadvantage; and although this procedure does not obviate the necessity for the use of such remedies as digitalis, it frequently enables them to exert their physiological action, where this had been abrogated by reason of the heart being incapable of overcoming the resistance of an excessive

volume of blood. A somewhat similar regimen to that advocated in cases of atonic dilatation of the stomach is found of great value in heart disease, and if at the same time the diet be salt-free, under the influence of appropriate diuretics the kidneys will act freely, œdema be relieved, and the case make satisfactory progress, when such a termination had been despaired of before the change of diet had been instituted.

By restriction of the consumption of liquid to less than 30 ounces daily Haig declares that he has been able to lower the blood-pressure by 20 to 30 mm. of mercury, with relief of the symptoms of hypertension, viz., headache, epilepsy, and depression.

Dry Diet in Kidney Disease.—It almost takes one by surprise to find that certain chronic renal diseases are found to derive great benefit by limitation of the allowance of drinks, but on calm reflection one must perceive that such a procedure is only a further example of the principle of lightening the burden of a weakened organ. The kidney excretes practically half of all the liquid which is swallowed, and so long as this quantity is not reduced below the amount required for the elimination of the urinary end-products of metabolism, nothing but good can accrue from diminishing the labours of an already overtaxed organ. In the only cases which are found suitable for this restriction of liquids, viz., those of chronic contracted kidney, it is found that the fluid intake may be reduced as low as $1\frac{1}{2}$ or even $1\frac{1}{4}$ litres without any risk. Even in acute nephritis it is wise just at first to lessen the consumption of fluids, unless uræmia should develop, when water may be administered freely.

Drinking in Obesity.—Whatever doubts may have existed in the layman's mind with regard to the advisability of reducing the input of liquids in the diseases we have just mentioned, he has never had any difficulty in believing that such a procedure is absolutely demanded in cases of obesity, and medical men in all ages have encouraged the perpetuation of this idea. Methods based upon this conception have been in existence from time immemorial, but it was in 1884 that Dancel, a French veterinary surgeon, placed them upon a scientific basis by his observations that the ingestion of much

water or watery foods had a powerful influence in causing great abdominal development in horses. Mere reduction in the quantity of fluid consumed caused a rapid diminution of weight and an increase of vigour, whereas an additional allowance of water to thin horses soon resulted in augmented weight. He therefore counselled a similar system for human beings, enforcing at the same time abstinence from fatty and farinaceous foods, frequent aperients, and outdoor exercise.

The method of treating obesity associated with Banting's name was modelled on the same lines. The systems of Ebstein and Oertel likewise reduce the consumption of fluids even in normal quantities as a favouring agency in the development of adipose tissue, but the former recommends an increased ration of fat with a minimum of carbohydrates and proteins, and the latter a large allowance of proteins, a diminished quantity of fats, and the almost total exclusion of carbohydrates.

Oertel in addition recommended that the food should be partaken of separately from liquids, contending that in this manner the blood was depleted of fluid by the demands made for the secretion of gastric juice. He was satisfied that, by the measures he instituted, not only was there an increased concentration of the blood and a dehydration of the tissues, but that deposited fat was actually consumed by a process of oxidation.

Another advocate of a similar system to Oertel's was Schweninger, whose explanation of the reduction of weight effected by his treatment was that the thirst engendered by the restriction of liquid caused the body to manufacture water from its own fatty tissues by splitting the fat into simpler molecules.

In each of these systems, as in all others with a similar object, in addition to the deprivation of water, other measures, such as hard exercise, massage, and a reduction in the amount of solid food, were laid under contribution, so that it is difficult to attribute any loss of flesh to the drink restriction alone. Further acquaintance with the subject also elucidates the fact that a great reduction in the allowance of fluids always results in an impairment of the appetite, so that the quantity of food ingested is necessarily diminished.

It is to be noted that in obesity nitrogen equilibrium is

usually maintained without a corresponding maintenance of carbon equilibrium. The aim, therefore, in dietetic treatment should always be to maintain nitrogen equilibrium, and to restrict the carbonaceous income, so that the output of carbon may be increased at the expense of the adipose tissue. In this connection it is important to remember that dry starch contains 44.2 per cent. of carbon, whilst dry fat contains 76.5 per cent. of carbon. It is essential, however, not to administer too much protein food, as although protein metabolism will gradually increase and nitrogenous equilibrium be established at continually higher levels, the amount of fat burned correspondingly diminishes, and there is even a risk that some of the carbonaceous moiety of the ingested protein may be retained in the body. For this reason Moritz has recommended an exclusive diet of milk in the treatment of obesity.

An interesting dissertation on the study of thirsting in animals is contributed by von Noorden, and serves as an introduction to observations made on his own patients. He mentions that Gürber, in a thirsting frog, found an increase of the erythrocytes, while in a thirsting dog von Westendorf noted that both the osmotic pressure and the specific gravity of the blood were increased, and that, whereas venesection is in such circumstances followed by a lowering of the specific gravity of the blood, this did not occur, because the dehydrated tissues were unable to yield more water to the blood. Landauer demonstrated on dogs that destruction of albumin is increased by thirsting, and this was corroborated by Straub, who likewise showed that in addition to the increase of urinary nitrogen, the excretion of P_2O_5 was also increased. Most important of all, however, as bearing upon the oxidation of fatty tissue, the last mentioned observer found that the excretion of carbon dioxide via the lungs and skin was not appreciably augmented.

Dennig verified most of these results, and also noted a gradual daily diminution of the insensible perspiration. He arrived at the conclusion that the end-products of the decomposition of albumins were retained until they were washed out of the tissues by subsequent water-drinking, and that they were formed in greater abundance in subjects who were lean than in those who were fat. It must be borne in mind that

this albumin destruction only occurs when drink restriction is carried to great excess, *i.e.*, when the amount of liquid consumed is limited to from 300 c.c. to 500 c.c., and that even Oertel never reduced the quantity below 1 litre, inclusive of the water contained in the food. But it is risky to venture to such extremes, even as this, for despite the careful superintendence of trained medical men, a system permitting the ingestion of less than 1,000 c.c. of liquids, excluding the water contained in the food, is not free from danger, because with such a regimen cases of renal calculus, colic, gout, albuminuria, and even fatal œdema, are on record.

Von Noorden himself could discover no evidence that there was any increase in the oxidation of fat, as the total oxygen metabolism of the organism is not augmented during thirsting. The first effect of continued thirsting, even in a normal case, is a loss of that variable quantity of fluid always contained in the tissues, because of the consumption of water, so that its withdrawal will effect the loss of this fluid. In other words, an actual dehydration of the tissues has taken place, and although there is an unquestionable loss of weight by the means described, there is really no loss of flesh, because the moment water-drinking is resumed in most cases the body-weight again increases. Loss of fat, therefore, is not a primary consequence of fasting, as asserted by Oertel and Schweninger.

It is very different, however, with many cases of obesity, because, especially in the older subjects, one has to reckon with the retention of water due to the accumulation of chlorides, so that many pounds of what amounts to œdematous fluid may thus be excreted in them. There can be little harm in losing this at any time or in any case, but any attempt at further reduction in the weight by possible increased oxidation of the fatty tissues must be undertaken with great caution, especially in the aged.

Von Noorden, whilst noting the fact that the appetite is impaired by limiting the drinking of fluids, was careful to insist that this in no way interfered with the digestive capacity, which is not at all lessened by the dry diet, and he expressed his belief that a normal or even increased quantity of fluid might be consumed between meals without diminishing the

loss of weight effected by the limited diet. Other observers have even contended that loss of weight is promoted by this procedure.

In conclusion, therefore, one may recapitulate the good results of the restriction of liquids briefly as follows: relief to an overburdened stomach and cardio-vascular apparatus, dehydration of the tissues and blood, with reduction of the body-weight, diminution of appetite, and, when carried to the danger limit, increased destruction of albumin, but no irrefutable evidence of actual combustion of deposited fat.

As a therapeutical procedure, it is indicated in chlorosis and serious hæmorrhage as well as in the conditions already mentioned, and in many such cases, as also in some of severe ascites, has been found of decided value. When, on the other hand, the body has lost an excessive quantity of its tissue and circulatory fluids, prompt measures must be taken to replace them, either by transfusion of blood or the infinitely simpler introduction of normal saline solution, either into the rectum or the subcutaneous tissues (hypodermoclysis).

CHAPTER IX

THE THEORY AND PRACTICE OF EFFICIENT MASTICATION

WE must now engage our attention with dietetic theories which have little or no relation to the alimentary principles excepting in so far as they introduce a particular mode of preparing them for the great purpose of nutrition. They are, however, pregnant with interest, if it were only because lurking behind whatever conception or misconception gives them their title we shall almost certainly encounter the great doctrine of moderation. Most of the systems, indeed, are only a subterfuge for practically instilling this fundamental truth into the minds of those who could not otherwise be persuaded to control their appetites, but are successfully appealed to by the elevation of some minor detail of eating and drinking into a cult. This is unquestionably the most potent factor in the amazingly rapid dissemination of the doctrine of efficient mastication.

"At the great Battle Creek Sanitarium, where sometimes upwards of a thousand patients and often a thousand employees are busy as bees in studying the laws of health and efficiency, and where physical culture is one of the most vital departments, there is exposed a huge sign, 10 feet long and bearing letters a foot deep, with the legend 'Fletcherise.' " The full significance of these words cannot be estimated without a short history of their author, Mr. Horace Fletcher. An American layman of independent means, and just turned sixty years of age, he was some twenty years ago refused for life assurance on the ground of physical disability, chiefly from indigestion and obesity. Being a man of observation, imagina-

tion, and resource, he determined to devote himself to elucidate the etiology of his condition. After much careful and intelligent study, he formulated the law that food should never be eaten without an appetite sufficiently discriminating to be satisfied only with the article consumed, that it should be masticated till all the taste had been extracted from it, and only swallowed when what he called the swallowing impulse had been excited. This is the theory underlying the practice of what is by many termed "Fletcherism," to the promulgation of which its author has since its inception devoted his life, and a particularly interesting account of which is enshrined in a special treatise consecrated to its propagation.

Fletcherism.—In the pages of this book he declares he has "found a way how not to eat too much, while eating all that appetite desires, and in a way that leads to a maximum of food taste and at a minimum of cost and waste." The treatment of food in the mouth is the only mechanical responsibility we have in our nutrition, and the only digestive process over which we have any direct control. His teaching is that we must wait for an appetite which we have earned by hard work, and when this has guided us to the selection of the special food demanded for the moment by our body, that we must then masticate or otherwise treat it in the mouth until it is thoroughly liquefied, neutralised, or alkalised by the saliva, and until the resultant material settles back into the glosso-epiglottidean folds behind the circumvallate papillæ and excites the swallowing reflex. Only what excites this reflex must be swallowed, and the rest must be still further "chewed at"—even although liquid—until the final portion of it disappears in response to the swallowing impulse. There is no exception to this rule, except in the case of water, which he declares has no taste. Nothing must be forcibly swallowed, as it is much safer to get rid of it beforehand than to risk putting it into the stomach. The idea involved in this last sentence is the only warrant I can find for the statement usually made that he recommends the tasteless fibrous residue of the food to be rejected—pulled out of the mouth by the fingers—and placed on the plate.

He claims for this plan that in an incredibly short space of time all digestive troubles will cease, that a relatively small

amount of food is sufficient to satisfy the appetite, and that although there is a preliminary loss of body-weight, the general health and activity are immensely augmented. Those who practise this system find that their fæces are much reduced in quantity, not more than 2 ounces per day being evacuated, pilular in form, separate or massed together, perfectly odourless and aseptic, and of such consistency that no soil-paper nor any other form of cleansing is required. Defæcation rarely occurs oftener than twice a week, and may be as infrequent as once in a fortnight. The presence of odour or offensive matter in the fæces is a distinct evidence of careless mastication.

Van Someren's Researches.—Having proved the efficiency of this system in his own person by being accepted for life assurance about a dozen years ago, he nevertheless found the greatest difficulty in getting scientists to accept his views or even to give him a patient hearing. That he finally succeeded is due probably to the conversion of Dr. Van Someren, who, in 1901, at the annual meeting of the British Medical Association, read a paper on the subject in the physiological section. Dr. Van Someren therein referred to some experiments in which the fæcal discharge was as little as 18·9 grams, dry and inoffensive, and he contended that this must be infinitely healthier for the individual than the daily evacuation of 204 grams of humid, decomposing, offensive matter. He quotes Nuttall and Thierfelder's experiments on full-term guinea-pigs, obtained by Cæsarean section and fed successfully on aseptic foods, to demonstrate that bacteria are not necessary to digestion. In the practice of efficient mastication he declares that the lower bowel ceases to be a putrefying sink, and that auto-intoxication thus becomes impossible.

This statement of Dr. Van Someren, made nine years ago, has now received confirmation, for in his recent remarks on the *Pteropus medius*, Metchnikoff has abundantly demonstrated that although bacteria play an important part in intestinal digestion, they are by no means essential. The *Pteropus medius* is a bat, with a very short colon, living chiefly on fruit. Of this it eats an enormous quantity, as its digestion is rapid, and the fæces contain a fair amount of undigested material. Practically no bacteria were found either in the

small or large intestine, and yet cellulose was extremely well digested. Another chemical delusion is thus shattered, and further research must be undertaken to isolate the enzyme. No indol, skatol, nor phenol was found, proving that these products are the result of putrefaction due to bacterial action.

This paper of Van Someren's induced Sir Michael Foster to interest himself in Fletcher's practice, and in the autumn of 1901 an investigation was carried out at Cambridge under the supervision of Sir Michael Foster and Dr. Gowland Hopkins. This resulted in a complete confirmation of Fletcher's contention that the amount of food which he consumed was enormously lessened, being hardly one-half of what he had previously consumed, and, in particular, that his protein food was reduced to nearly one-third of the amount which had been held to be the minimum. Subsequently, in 1902 and 1903, Professor Chittenden subjected him at Yale to further tests, both in nutrition and muscular strength, with a like result. During thirteen days in which his weight of 165 pounds remained practically constant, Fletcher only metabolised a daily average of 41.25 grams protein.

His strength and endurance were repeatedly put to the test by Dr. W. G. Anderson, the superintendent of Yale Gymnasium, and although living on an extremely attenuated diet, both appeared to be on the increase. At any rate, some two years ago, at the age of fifty-eight, Mr. Fletcher lifted a dead weight of 300 pounds more than 350 times with the muscles of his leg below the knee. This is a remarkable feat of strength, and constitutes a record, as the previous best was 170 lifts, and only two men have exceeded 100 lifts. This mighty dynamometer, invented by Professor Irving Fisher, can still be seen at Yale University Gymnasium, and either the man who created the above record is a prodigy or the dietetic system which he advocates is miraculous in its results. He maintains the latter proposition, and contends that the system is capable of manufacturing muscle. He even refers to Dr. Anderson, in the article already quoted, as an example of this teaching, and states that although the latter is well over middle-age he has been able, by adopting "Fletcherism" and systematic work of not very arduous character, to add 15 pounds to his weight. Dr. Anderson himself is inclined to

attribute this improvement in health and growth of muscle to the low-protein diet, but as the system we are now considering is said to compel a low-protein diet, it is not incompatible with Fletcher's claims.

Fisher's Experiments.—In recent years many other experiments confirming those of Mr. Fletcher have been conducted. At Yale University, five years ago, a band of nine students undertook an experiment to test the virtues of thorough mastication. The experiment was divided into stages, in the first of which the following two rules were observed :—

(1) To masticate thoroughly every morsel of food, with the attention concentrated not upon the mechanical act of chewing, but upon the taste and enjoyment of the food.

(2) To follow implicitly and absolutely the dictates of the appetite both as to the amount and kind of food chosen.

During the second stage a third rule was added, viz. :—

(3) To use reason when instinct was in doubt.

To enable this to be put into operation the foods were divided into two lists, one in the tentative order of intrinsic merit, beginning with the fruits and ending with alcohol, the other in the proportion of their protein-content. The men were then instructed when their appetites were entirely willing to acquiesce, and only then, to select the better and purer foods and those with a low protein-content in preference to those with a high protein-content. Careful physical tests were instituted, and the excreta were examined in the laboratory of the Sheffield Scientific School.

At the conclusion of the experiment the following were the phenomena noted. Whilst there was a slight reduction in the total amount of food consumed, there was a large reduction in the consumption of protein-containing foods, especially flesh foods, a diminished excretion of nitrogen, a reduction in the odour, putrefaction, fermentation, and quantity of the fæces, a slight loss of weight and strength, an enormous increase of physical endurance, and a slight increase in mental alertness. Irving Fisher concludes that there is much evidence in this experiment to show that thorough mastication is "natural" to man, and that its adoption is certain to lessen the consumption of foods containing a large proportion of protein

and to encourage the use of those, especially of the fleshless variety, containing less protein. Although Irving Fisher is not a medical man he is recognised to be a careful observer, and I think that he is justified from the evidence in this experiment in concluding that better results in nutrition and endurance are obtained by efficient mastication and thorough insalivation than when these functions are neglected. In this and subsequent experiments at Yale and Brussels it was found that the closer the approach was made to vegetarianism the greater was the endurance, whilst without having any more strength, the vegetarians had by far the greatest endurance of all. Although Fisher does not make the statement specifically, he is inclined to institute a comparison between carnivorous and granivorous or fleshless eating animals in this connection.

Psomophagy and Poltrophagy.—A very interesting contribution to this side of the question has been made by another disciple of Mr. Fletcher in the person of Dr. Hubert Higgins, late of Cambridge, England. In this paper he relates how he practised thorough mastication for a considerable length of time, setting himself to make a complete research into the anatomy and physiology of the process, and also to discover its application in the therapy of chronic disease. He discovered that Gegenbauer had noted that the powers of swallowing may be classified in two forms, depending upon whether the food is subjected to excessive comminution and thus very finely divided or is simply bitten without being masticated. Thus he differentiates between poltrophagic and psomophagic animals, the former representing those which practise Fletcherism and the latter those who only bite their food before swallowing. Man is obviously psomophagic, but has the necessary anatomical structure in his soft palate to enable him to become poltrophagic. The horse is a typical example of a poltrophagic animal, and its soft palate is so close to its tongue that it cannot breathe through its mouth. The dog, on the other hand, is essentially psomophagic.

The kinds of swallowing in man may be illustrated by the swallowing of water. In the psomophagic method the water is simply pushed against the soft palate by the tongue; in the poltrophagic method the process is much slower, and is

carried out by employing movements of mastication on the water, which soon becomes warm, and, as this condition arises, is automatically carried into the cesophagus by a series of short deglutitions. He concludes that the soft palate in man and the poltrophagic animals is an organ for the digestion of starch in the mouth, thus supporting Fletcher's contention that there is a natural reflex in the region of the glosso-epiglottidean folds only excited by foods specially prepared by prolonged mastication.

On the other hand he is convinced that prolonged conscious mastication with the rejection of all fibrous material does harm—unless where atony of the colon exists—by causing coprostasis and inducing atrophy of the muscular coat of the intestine. He counsels caution in the adoption of any of the theoretical dietetic practices and believes that the evil results of a too long continuance of Haig's or Chittenden's method may work irreparable damage on the system, although the effects may be slow in declaring themselves. In other words, he gives convincing testimony of the utility of careful mastication, without such excessive attention to this or any other dietetic practice as is advocated by their respective promoters. From this point of view, therefore, he is a powerful supporter of the practice of moderation in all things, the conclusion at which most men arrive who take the trouble to investigate any of the exaggerated procedures.

Functions of the Saliva.—But in reference to the subject under consideration, practically everything of really effective value which has been advanced by Fletcher was known long before his time. I find that in 1891 Professor John Goodfellow, of the Bow and Bromley Institute, made a special study of the secretion and function of the saliva, the results of which were reported in the *Vegetarian* for June of that year. He found that in 50 grains of dry wheat-bread, thoroughly masticated and insalivated for sixty seconds, 10 per cent. of the contained starch was converted into maltose and dextrin, whereas when moistened and only masticated for fifteen seconds—which is the average time allowed for moist foods by the fairly careful eater—only 2 per cent. of the contained starch was converted into maltose and

dextrin. His next experiment consisted in the mastication for five seconds of 100 grains of oatmeal-porridge mixed with milk and cane sugar, and the determination of its effect on the contained starch. He discovered that it was practically nil, not more than one-half per cent. being converted. He therefore concluded that very little of the starch of our food is converted into sugar in the mouth during ordinary mastication, pointing to the fact that the function of the saliva is to moisten the buccal cavity and facilitate the formation of a bolus.

His further experiments included some made on raw starch in uncooked grain, and of this only an insignificant portion was converted into maltose and dextrin. Dr. Densmore, who quotes these cases, falls into the error of imagining that no starch digestion takes place in the stomach because the alkaline saliva is neutralised and its functions destroyed by the acid gastric juice. On this he founds the argument that food fruits, *e.g.*, figs, which contain as much as 68 per cent. of glucose, should be eaten in preference to bread and other starchy foods. We now know, of course, that for quite an hour, or even in some cases longer, the diastatic action of the saliva continues to be exercised in the stomach. These results are in accordance with those obtained at Battle Creek Sanitarium in the daily examinations in the laboratory.

Two points emerge prominently from this statement:—(1) that from the point of view of the amylolytic effect of saliva during thorough mastication and insalivation Mr. Fletcher was by no means first in the field, (2) that effective mastication has a powerful influence on the digestion of starch in the mouth, but this is not nearly so great as is supposed. Mr. Fletcher, in his powerful advocacy of the practice associated with his name, gives one the impression that all the starch in the food is converted into maltose, and that its digestion is capable of being completed in the mouth, thus giving the pancreas infinitely less work to do and clearing the way for the better digestion of protein in the stomach. But it is evident that this is not the case, and that at any rate in the present evolutionary stage of gastric digestion the stomach has a function to perform in the digestion of carbohydrates.

It is possible—one is safe to say absolutely certain—that the average man is guilty of neglect in mastication, but this appears to be a matter of insignificant importance with a vigorous, healthy digestion. When, however, from any cause this has been lost, thorough mastication is of infinite value, not only because it brings about complete subdivision of the food into particles minute enough to be easily dissolved by the various digestive fluids, but because it is maintained by many that the greater the amount of effective saliva which is secreted, the greater will be the proportion of gastric juice. It is known that alkalis stimulate the secretion of acid—although Pavlov teaches that it is not the alkali but the water in which it is dissolved that excites the secretion—and on this footing alone a more effective gastric juice would be secreted. But it is not at all impossible that absorption of maltose takes place from the stomach in fair proportions, and that this has the effect of an internal secretion in stimulating the secretion of the chemical juice of Pavlov. I frankly admit that the evidence in favour of such a hypothesis is scanty in the extreme, although there is a certain amount of warrant for the statement that sugar in minute proportions is absorbed from the stomach. It is further known that the larger the quantity of gastric juice, the greater will be the quantity of pancreatic fluid, bile, and intestinal secretions; and if the observation is reliable that the saliva is not destroyed in the stomach, but its action only inhibited, and that it is reactivated in the intestine, the total digestive power from all the secretions will thus be strengthened by effective mastication and insalivation. Thus the healthy man can ensure the retention of his vigorous digestion and the dyspeptic has an equal certainty of increasing the chance of its restoration by careful chewing.

To encourage this inestimable practice it is important to consume at each meal a sufficiency of dry food, *e.g.*, toast, or better still zwieback, because of its contained dextrin. Pavlov's experiment demonstrated the fact that dryness of food is the property which above all others stimulates the secretion of saliva. He measured the amount of saliva produced by holding a marble in the mouth, then converted the marble into dust, returned it to the mouth and again measured the quantity of saliva secreted, finding a very large increase.

An ounce of dry flakes, according to Kellogg, when chewed in portions during five minutes, is capable of giving rise to the secretion of 3 ounces of saliva, whereas moist food evokes a very small secretion indeed. It is also known that the act of chewing itself is responsible for an outflow of saliva, for chewing food on one side only will cause a secretion of three times more saliva on that side than on the other.

Bearings of the Theory.—It may be conceded, therefore, that although there is nothing novel in the practice of effective mastication—which Dr. Harry Campbell considers one of the lost arts—it is quite certain that Mr. Fletcher has forcibly directed the attention of civilised mankind to this intermission of its duty by so emphatically preaching his doctrine. The claim that it encourages the adoption of a low-protein diet is quite intelligible, although for the same reason it should tend to a diminution of the fatty content of the food. The longer carbohydrates are masticated the sweeter they become from the development of saccharine material, but as proteins have no flavour other than that imparted by the extractives with which they are associated, there is no pleasure to be derived from their prolonged retention in the mouth, and the tendency is to reduce their quantity. Obviously the same argument applies to fats, and so it comes that, in common with the herbivora and granivora, poltrophagic man tends to become a vegetarian, depending largely on cereals, grains, and fruits.

So far as one can judge from the facts at our disposal, no evidence has been adduced for the existence of any swallowing impulse or reflex other than the ordinary complicated reflex of deglutition so familiar to modern physiological students. Our knowledge of the position of the epiglottis during deglutition has within the last few years undergone a complete revolution from the orthodox teaching that it dropped back over the glottis at the psychological moment to prevent the ingress of any particles into the larynx. It is now pretty well ascertained that the larynx is drawn upwards and forwards beneath the tongue, so that the glottis lies just below the base of the epiglottis, and the posterior surface of the latter is that which comes into contact with the food during swallowing. If this be the case, the glosso-epiglottidean folds will hardly be much in evidence, and it has been proved by experiment that

after complete removal of the epiglottis swallowing can be accomplished without any difficulty and without the entrance of substances into the larynx. In any case, I have met no physiologist or dietist who believes in the existence of this new reflex.

Then, again, the weight of evidence is against the removal of all tasteless solid residue left after the "fletcherising" process is complete. It can hardly be a tax upon "available mental and physical power," as it is absolutely necessary to provide some ballast for the entanglement of the essential element of the fæces, viz., that fluid portion excreted from the bowel wall, presumably from the blood. Although Kellogg is a strong supporter of effective mastication, he joins issue with Mr. Fletcher on this point, because he not only teaches that three daily evacuations are necessary, but that on the concentrated and dextrinised nut, cereal, and fruit preparations which are the important ingredients of the fleshless feeder's diet, it is requisite to supply a large quantity of indigestible, insoluble cellulose in the form of agar-agar. This is his own practice, and he testifies that since adopting it he has been cured of undoubted auto-intoxication, which existed when he had to be satisfied with one daily evacuation.

During Cetti's fasts there was always a considerable amount of fæces—to be exact, an average of 22.01 grams daily—and in the light of the above facts we are not surprised to know that the excretion of indol was increased.

We have already seen (see Chapter IV.) that Benedict demonstrated by means of the calorimeter that Mr. Fletcher consumed much more than he imagined, so that though there was a diminution of the protein, there must have been an increase of the carbohydrate element, and this is what we find, because his diet consisted of prepared cereal, maple sugar, and milk.

The conclusion, therefore, at which we must arrive is that during health nothing more than ordinarily careful mastication is necessary, and that, if permitted at all, the exaggeration of this function as represented by Fletcherism should be reserved for certain classes of dyspeptics.

CHAPTER X

THE "CURDLED MILK" THEORY AND PRACTICE

MILK shares with honey the distinction of being the only dietetic agency which is originally intended for this purpose and no other, and is practically the only food containing all the alimentary principles in anything like the normal proportions.

MILK AND ITS PROPERTIES

Being, therefore, a typical natural food, it is used very freely alike among civilised and uncivilised peoples, and it possesses the additional features of being moderately cheap and easily digested. This last property is due to the fact that it is not dependent upon the "appetite juice" demanded by all other foods, and that it requires very little gastric and pancreatic juice for its complete disposal. It is also a very staying and economical food, because Pavlov has proved that twelve hours after its ingestion it has only parted with 15 per cent. of its nitrogen, whereas bread has given up 50 per cent. of its nitrogen, a circumstance which has suggested to him the initiation of dietetic experimentation with a view to classifying foods in accordance with their economical properties.

A proof of its extraordinary ease of assimilation is indicated by the fact that it can be utilised by the system after direct injection into the veins; but for all this it is by no means easily tolerated by every person. Probably this is in no small measure due to the common occurrence of hyperchlorhydria amongst a meat-eating community, because, if a glass of milk be administered an hour before meals in a normal stomach,

which should then be empty and contain no acid, and the recumbent position be assumed, it is all absorbed before meal time. Finally, Rubner has shown that on an exclusive diet of milk—2,438 grams in quantity—containing 84 grams protein and two-thirds of the energy requirement of the individual, no less than 6·7 grams of protein were added to the body daily. To supply 2,400 calories daily 3,410 grams of milk would be necessary, and this contains 140 grams of protein, which would be too much for a normal adult. For this very reason, however, milk constitutes an excellent diet for growing children or invalids convalescing from a wasting disease.

Consequently, in all ages efforts have been directed to the preparation of more suitable forms for its administration to those who have difficulty in digesting it, and in this way koumiss, which is a fermented preparation of mare's milk, and kephyr, an ally made from cow's or goat's milk, have been introduced. Both of these fluids contain lactic acid, butyric acid, carbonic acid, and alcohol, and have been largely used in the East and elsewhere in the treatment of inflammation of the colon alike in children and adults.

Probably in this country at least the kephyr and koumiss cures will speedily lapse into oblivion, on account of the introduction of the treatment of intestinal and other affections by "soured" milk, or lacto-bacilline. It is important to note that "soured," or as it is often called "curdled," milk is not simply sour milk, but a definite preparation of fresh milk, curdled by the activity of the Bulgarian or Massol's bacillus in the presence of its associate, the *Bacillus acidi lactici aërogenes*, produced in symbiosis. This last bacillus, first isolated by Lord Lister, and described by him under the name of *Bacterium lactis*, is always present in milk, is quite harmless, and improves the taste of the curd, whereas it is always necessary to add the former. Lister pointed out the interesting fact that the *Bacterium lactis* is not to be found in the milk as it comes from the cow, but obtains access in the dairy, and that whilst universal in dairies it is rarely to be found elsewhere.

Sour milk, or buttermilk, is the residue left after butter is made from cream, and contains, besides water, $2\frac{1}{2}$ per cent. protein, 1 per cent. fat, $3\frac{1}{2}$ per cent. sugar, with a considerable amount of lactic acid which has been formed from the sugar.

It is freely consumed by the peasantry of Scotland, Ireland, and Bulgaria—in the first-mentioned country being usually eaten with oatmeal-porridge, in Ireland with potatoes, whilst in both it is used as a beverage during harvesting and other agricultural operations. It is not so well known in England, but something akin to it was utilised by the middle and lower classes in the Middle Ages. Harvey, in his notes of the autopsy of Thomas Parr—"Old Parr," who is stated to have lived to the age of 153 years—mentions that the body was sound and "young," and he apparently thinks this rather remarkable, as "his ordinary diet consisted of sub-rancid cheese, and milk in every form, coarse and hard bread, and small drink, generally sour whey."

Soured Milk or "Yoghourt."—Whether this was the original preparation used in Bulgaria from which the present day curdled milk has been evolved it is difficult to say, but it is certain that yoghurt, or yoghurt, is now in the home of its birth made from a special ferment called "maya." This contains several yeasts and bacilli, besides the bacillus Bulgarian or bacillus of Massol, and the *Bacillus acidi lactici aërogenes*, amongst them being the *Streptococcus lebenis*, the *Mycoderma lebenis*, and the *Saccharomyces lebenis*. This specific substance has been used from time immemorial in Eastern Europe as an article of diet, and some thirty or forty years ago was much in vogue in France.

Although it is therefore the revival of an old treatment, it has been rescued from the haphazard methods in practice by the scientific acumen of Professor Metchnikoff, so well known for his work at the Pasteur Institute in Paris. He has demonstrated that the essential organism involved in its preparation is the Massol bacillus—first isolated by Grigoroff in Massol's laboratory in Geneva—in association with the *Bacillus acidi lactici aërogenes*, and that the others are not only unnecessary, but may in some cases be harmful.

When sweetened sterilised milk—or, as Metchnikoff advises, skimmed milk—at the correct temperature is inoculated with these two germs, lactic acid is slowly formed, and the caseinogen is altered to casein in the form of clots or curds. The longer the process is allowed to continue the more lactic acid is formed, but it can be inhibited by raising to boiling

point or suspended by placing on ice. Thus prepared, the milk is of semi-solid consistency, and besides the alteration in the sugar—and any sugar is acted upon excepting saccharose and maltose—some of its constituents are partially digested; in particular, a goodly proportion of the casein and phosphates is rendered soluble. Metchnikoff says: "A large proportion (38 per cent.) of casein is rendered soluble during the fermentation, which shows that its albuminous matter is prepared for digestion. Of phosphate of lime, which is the chief mineral substance of milk, 68 per cent. is rendered soluble during the fermentation." For this reason it is more easily tolerated by many people than ordinary milk, and in any case is in effect a therapeutic agency, being virtually a pure culture of lactic acid bacilli, each pint of milk being estimated by Professor Tanner Hewlett to contain 400,000 millions of bacilli.

Now as lactic acid, like most acids, is antiseptic and germicidal, even when found in ordinary milk which has accidentally gone sour, and as to a certain extent it protects such milk from the invasion of putrefactive organisms, it is only necessary to introduce it in suitable form into the alimentary canal, there to combat the growth of the germs of putrefaction. This is the contention of Metchnikoff, whose attention was first directed to the subject when investigating the cause of old age. Impressed by the longevity of birds possessing no colon, and by the persistent use of curdled milk in Bulgaria by its many centenarian inhabitants, he could not refrain from associating these two facts. He had previously—whilst studying the etiology of cholera—discovered that the intestinal canal of the ordinary healthy man always contained a great number of varieties of bacteria. He was forced to the conclusion that many of the toxins known to abound in the alimentary canal were the direct results of the activities of these micro-organisms, and thus began that brilliant research which has served to make his name practically a household word amongst the nations.

Bacteria and Toxins in the Colon.—Probably the pioneer in this study was Bouchard, who almost a quarter of a century ago enunciated the doctrine of auto-intoxication, declaring that, apart from the poisons swallowed in our foods, the alimentary canal was flooded with toxins which were products of the

decomposition of food. Many of the end-products associated with the undigested particles of proteins, chiefly in the colon, are not really toxic, and comprise members of the fatty series, *e.g.*, the amino-acids, leucin, alanin, aspartic acid, glutamic acid, butylalanin, glycocoll, the aromatic series, tyrosin, tryptophane, phenylalanin. But there are likewise present more decidedly toxic substances, partly derived from the disintegration of some of the foregoing, *e.g.*, indol, skatol, cresol, leucomaines and ptomaines, such as putrescin (derived from arginin), cadaverin (the product of lysin), muscarin, neurin, and various poisonous gases.

He conjectured that bacteria had much to do in this production, but it was reserved for later workers to isolate and differentiate them. Inasmuch, however, as ethereal sulphates, indican, &c., were to be discovered in the urine, this was considered to be conclusive evidence that the toxins had gained an entrance into the circulation through the intestinal wall. As the alimentary canal of a newly-born child is perfectly free from microbes—which soon, however, obtain admission, and eventually swarm therein—it is easy to understand that as years roll on it develops into a condition far from aseptic.

Amongst others, Cohendy and Tissier have given much careful study to the intestinal bacteria, and they assert that although the number of the species is limited, quite two-thirds of the fæces is composed entirely of bacteria, chiefly of the anaërobic variety. Cohendy estimated that every milligram of fæcal matter contained something like 150 million bacilli, of which, however, only about 3 per cent. were alive, although the others had lived for some time in the bowel. The character of these micro-organisms varies according to their position, but they may be roughly divided into two classes: (1) Saccharolytic, or amylolytic, organisms, which feed on starch, sugar, dextrin, and hydrocarbons generally. These produce acid substances such as lactic, acetic, succinic, butyric acids, which, although irritants and more or less harmful in character, are not deadly poisons, some of them appearing to exert a restraining influence on putrefaction. (2) Proteolytic micro-organisms which feed upon nitrogenous substances, these undergoing successive transformations until

they produce toxins of putrefaction, highly offensive to smell and taste, and ranking among the most deadly poisons known. The saccharolytes are found principally in the small intestine, while the proteolytes almost entirely inhabit the colon.

Although there are other micro-organisms such as the peptolytes, which normally inhabit the intestinal canal, these may be considered as the two chief divisions, but in addition there may be others which may have obtained access accidentally, *e.g.*, the comma and typhoid bacilli, the pneumococcus, &c. For the most part, however, these pathogenic organisms, which gain admission by the mouth, are destroyed by the gastric juice. The advantage of adopting this classification is that we can thus roughly divide the inhabitants of the intestine into two opposing categories, the one mainly harmful and the other harmless, if not indeed beneficial. This, in any case, is the claim made by Metchnikoff, and to demonstrate the active utility of many of these organisms he proved that chickens reared as far as possible without intestinal microbes languished and died, whereas others fed in the same way—though with a full supply of intestinal microbes—came to perfect development. His contention, therefore, is that bacteria are necessary to the completion of nutrition, so that what may be called a stupefying conflict is constantly being waged in the alimentary canal between the two classes of microbes, the proteolytes, which have a baneful effect on the system through their toxins, being inhibited—but not killed—by the saccharolytes, which have thus on the whole a salutary influence on the well-being of the individual. Now as proteolytes can only develop in an alkaline medium, and remain inert or inactive in an acid or even less alkaline medium, it will be seen that the colon is under ordinary circumstances entirely favourable to their development. He considers, therefore, that curdled milk, which is simply a pure culture of the most powerful lactic-acid-producing organism which is able to survive its passage through the stomach and go on producing its beneficial acid in a nascent condition in the colon, is an agency of the first order for improving the health and prolonging the life of the individual.

It has long been recognised that lactic acid has a beneficial therapeutic influence on intestinal ailments, Hayem having

administered it by the mouth with this intent, and Herter by the bowel for the same purpose. In the former case its action was futile, as it was rapidly decomposed into carbonic acid and water; but in the latter instance its use was followed by a distinct diminution of the ethereal sulphates and indican in the urine. The employment of the acid *per se* is, however, much inferior to the use of a means for manufacturing it *in situ*, especially as it has been proved that the lactic acid bacillus acts in an automatic manner, its own growth being inhibited when the total acidity from its own product has been reduced by decomposition of the excess of the lactic acid. It is important to remember, however, that any salutary influence accruing is to be attributed to the lactic acid and not to the germs.

It is an unquestionable fact that many organisms capable of initiating intestinal putrefaction have been isolated, amongst them being the *Bacillus putreficus*, which is spore-bearing, thrives in milk without causing it to coagulate, and digests the casein; the *Bacillus Welchii perfringens*, or *aërogenes*; and the *Bacillus sporogenes* of Klein. These organisms manufacture toxins, which pass through porcelain filters, resist a temperature of 100° C., and can kill rabbits. Their action, moreover, is somewhat capricious, as Welch's bacillus taken from a case of appendicitis proved almost inactive, whereas other specimens taken from quite healthy individuals were sufficiently powerful to kill animals. Fortunately, the normal individual is richly provided with antitoxic organs in the liver, thyroid, adrenals, to say nothing of the mucous membrane of the bowel and the skin and kidneys, so that it is a rare occurrence for the average individual who obeys the laws of health, and particularly who lives on a well-balanced varied dietary, to be deleteriously affected by the toxins manufactured in his alimentary canal. But conditions may and do arise constantly, due to exposure to cold, exhaustion, and especially failure to recognise the advantages of a varied and correctly proportioned dietary, when the antitoxic organs may fail in their beneficent labours, or the toxins formed may be in excess of their antidotal powers, and thus disease in some form is likely to arise.

Metchnikoff has proved decisively the extreme sensitiveness

of these bacteria to alterations in the diet, so much so that merely changing the particular brand of peptone is sufficient to produce a marked variation in the proportion of the micro-organisms. He inoculated with faecal matter two culture tubes, one containing minced meat and water, and the other minced vegetable and water. In two days the toxins of the former tube were sufficiently powerful to kill rabbits, whereas the latter, on being injected, proved quite innocuous, and the germs contained in the two tubes were quite different in character.

Herter and Kendall have also by feeding experiments shown that the character of the intestinal flora is directly connected with the nature of the food. These were conducted on monkeys and cats, which were fed on exclusively protein and exclusively carbohydrate food, the transitions from the one to the other being effected rapidly. On a protein diet, proteolytic bacteria abounded, and on a carbohydrate diet these organisms were rapidly replaced by others of an acidophilic, non-proteolysing type. At the same time there was a reduction of the aromatic oxyacids and indican in the urine, and indol, skatol, phenol, and bound sulphuretted hydrogen of the faeces, and the animals improved in spirits and activity. It is quite evident that the change of diet involved the destruction of the previous bacterial flora, and the authors remark that in intestinal disease, "where undeniable bacteria abound, both on a protein diet and on a carbohydrate diet, frequent alterations in the chemical nature of the diet are beneficial by interfering with the establishment of any one type of bacteria in the intestine."

Metchnikoff long ago suggested that to aid the body in its effort to protect itself against the toxic products of putrefaction it was wise to eliminate from the diet such articles of food, *e.g.*, meat, as conduce to intestinal fermentation, in favour of milk, which is much less liable to fermentative changes, and to reinforce the latter by the addition of the lactic acid bacillus. He declares that the poisonous excretions, which he indicates are paracresol and indol, being absorbed by the normal walls of the bowel, exercise in all cases a toxic irritant effect on the organism, producing an increase in the connective tissue of the organs and blood-

vessels, thus setting up sclerosis, endarteritis, and finally senile decay.

THE LIMITATIONS OF CURDLED MILK THERAPY

In consequence of these claims made for curdled milk, it is at present in great favour both with the medical profession and among the public, as a very valuable article of diet, and from this point of view, where it agrees with the individual, nothing but good is likely to result. Being a complete food, and easy to digest on account of the reasons already advanced; being also a powerful diuretic, a nervine tonic, and occasionally a convenient laxative, it cannot fail to produce a potent influence for good on the human body. It is even averred that its contained lactic acid increases the coefficient of the assimilation of food in the intestine, because Biernacki has shown that lactobacilline causes a diminution of the weight of the fæces, amounting to from 15 to 20 per cent. of dry matter, and likewise a reduction of their content of nitrogen and fat. This same observer remarks that nascent lactic acid stimulates intestinal digestion, and that lactic acid bacilli exert very energetic action on the digestive organs, and so improve digestion. This effect he suspects is due to stimulation of the secretions, which would explain the notable intolerance of the subjects of hyperacidity for soured milk. He also asserts that soured milk is astringent in certain diseased conditions of the intestine, although lactobacilline produces just the opposite effect in constipation.

Amidst an almost universal chorus of approval, this is one of the few dissentient voices which have raised a note of warning in the use of curdled milk, and it is to be observed that the evidence is somewhat contradictory. Curdled milk disagrees with the hyperchlorhydric patient because it stimulates the secretions. One would, therefore, have expected that on account of an analogous action on the intestinal secretion, it would have relieved constipation, whereas an astringent effect was noted. Personally, I can cordially corroborate both statements, because I have repeatedly observed that curdled milk always disagrees with hyperchlorhydrics, and almost always produces constipation, and I have

only known of a very few cases in which it acted as a laxative. I am informed by the superintendent of a large sanitarium in England that he has never known it to act as a laxative, although, on the other hand, he does not consider its effect is constipating. It is to be noted that milk contains more lime than lime-water, and although it is claimed that in curdled milk the phosphate of lime is rendered more soluble, this fact has apparently no influence in reducing the constipating tendency. In cases of hypochlorhydria, on the other hand, it is not only easily tolerated, but highly beneficial in its effect on digestion, and, by virtue of being a valuable nutrient, a most important addition to the nutrition of the body.

Rheumatism produced by Curdled Milk.—Perhaps the most serious indictment in connection with its use is the undoubted fact that it induces or initiates rheumatism, and I would like to draw attention to this fact on account of the many cases in which I have seen it produce this effect. In the days of my youth I had frequent opportunities of testing the value of buttermilk, both as a refreshing drink and a dietetic agency with oatmeal-porridge, but its use was invariably accompanied by severe indigestion. In more recent years I have suffered both from colic and indigestion from the use of curdled milk, and therefore did not persevere in its use. On my return from Battle Creek Sanitarium in 1909 I made a persistent attempt to habituate myself to, and, if possible, benefit by its use, and although by employing “Yoghurt” tablets, or capsules, I was able to obviate the indigestion, I repeatedly noticed after a few days—generally the third or fourth day—an exacerbation of a rheumatic pain in my right knee, so severe as to prevent me playing golf. That the pain was not imaginary, nor produced by suggestion, was obvious from the fact that two or three times when I started to take the tablets, in an effort to use them up whilst still active, and entirely forgetful of my previous experience, on the third or fourth day I was again pulled up by rheumatism. This induced me to watch other cases, and I have been able to note attacks of lumbago, sciatica, attacks of muscular rheumatism in various parts of the body, and an occasional effusion into a joint, all produced by its use.

Most physicians are in the habit of counselling their

rheumatic patients to keep free from even the slightest suspicion of constipation, knowing by experience how quickly this induces sciatica, lumbago, and fibrositis, and doubtless the constipating tendency of milk has something to do with these untoward results. But there is another factor in the case which is probably of more importance. For many years excess of acidity has been considered as being in some way associated with the production of rheumatism, and lactic acid has been mentioned as the specific agent involved. In the ordinary way it is discovered in the body as one result of indigestion, as also by the metabolic changes in muscle. We know that ammonium is also a product of protein metabolism, and these two substances being carried by the blood to the liver combine to form lactate of ammonia, $\text{NH}_3 + \text{C}_3\text{H}_6\text{O}_3 = \text{NH}_4\text{C}_3\text{H}_5\text{O}_3$, and this in ordinary circumstances is converted into urea. Now, in birds, the liver forms uric acid, and when it is cut out of the circulation lactate of ammonium is excreted instead of uric acid. It would therefore appear, at any rate in birds, that the liver transforms lactate of NH_4 into uric acid.

The close association of uric acid, urea, and lactic acid is surely more than a mere coincidence. The molecule of uric acid contains two molecules of urea, combined with an acid containing three atoms of carbon, viz., acrylic acid, which is simply dehydrated ethylidene lactic acid. Uric acid, indeed, has been synthesised by Horbaczewski from trichlorolactic acid and urea.

I make no claim for the recognition of lactic acid as a direct factor in the production of rheumatism—this was sufficiently disproved by Latham in the Croonian Lecture of 1886—but I do think that in common with many other acids it is an indirect factor. Now, when excessive quantities of lactic acid are formed by fermentation in the alimentary canal, or by feeding with lactic acid bacilli, there is no doubt that these can be absorbed, and it is conceivable that they may interfere in some way with the normal hepatic metabolism. In any case, the constant necessity for neutralising the acid contents of the bowel tends to withdraw alkalis from the system, and lessens the alkaline reaction of the blood, a condition analogous to that which occurs when too much acid fruit is consumed. We

have seen that rheumatism is often the direct result of such a practice, and it does not require a very vivid imagination to infer that in a similar manner it may be produced by excess of lactic acid, for, whatever the explanation of the rheumatism may be, it is closely bound up with the ingestion of more acid than the system can tolerate.

It should be carefully noted that curdled milk was introduced by Metchnikoff and his associates, less as an addition to our therapeutical armamentarium than as an item of our daily diet, and from this point of view it may be considered as the most powerful argument in favour of a low-protein diet. If harmful putrefactive organisms only infect the colon when there is a food supply for them in the shape of surplus protein not required by the tissues, then the simplest way to exterminate them is to desist from taking the extra protein. It is surely a work of supererogation, and certainly a waste of energy, to consume the useless extra protein calculated to form dangerous toxins, and at the same time swallow a by no means delectable antidote in the shape of a culture of lactic acid bacilli. But it has yet to be proved that the toxins which are undoubtedly formed are, except when in excess or where the natural protective organs are unable satisfactorily to fulfil their functions, any more dangerous than the irritating acids formed by the antitoxin, and it should be noted that butyric acid bacteria are anaërobic.

INDICATIONS FOR LACTIC ACID THERAPY

It should be borne in mind that lactic acid therapy is only indicated when the putrefactive anaërobic micro-organisms are in excess in the colon, and there is no guarantee that without such a guide this form of medication may not aggravate rather than alleviate the intestinal condition. It is not at all unusual for severe colic, and occasionally diarrhœa, to arise during a course of curdled milk treatment, and although such untoward symptoms may be anticipated just at the beginning, in many cases they do not always subside. It would be futile for me to deny the benefit frequently accruing during the treatment, but at any rate in muco-membranous colitis I have seen just as valuable results from fresh cow's milk, when it agreed with

the patient, as from the curdled milk. We are very apt to forget that there are other factors in the curdled milk treatment besides the lactic acid bacillus. Milk *per se* is a most valuable nutrient, and the new system is an excellent artifice for enabling recalcitrant patients, who object to ordinary milk, to obtain the unquestionable advantages of the continued use of milk. Nor is it to be forgotten that it often replaces the objectionable tea and coffee, which in most cases of intestinal ailments are decided irritants, and always nerve poisons in the neuro-arthritic type of patient. At the same time it diminishes the desire for flesh foods, because it possesses quite a respectable proportion of protein.

The longevity of the Bulgarian peasantry is not necessarily due to the use of soured milk. There are many other powerful factors in operation. The most important of these is an open-air life, with considerable muscular exercise, extreme moderation and simplicity of diet, absence of the nerve-exhausting occupations of civilised life, and the influence of heredity, an element whose potency must not be overlooked.

But is it quite certain that curdled milk is used with such frequency, or in such proportions, in Bulgaria as is being so constantly reported? My friend Mr. Frank Marsh, F.R.C.S., of Birmingham, who resided for eight months in a Bulgarian peasant's cottage, never once saw or heard of curdled milk whilst there, although he recollects that much fresh cow's milk was used, and naïvely adds that he saw more tuberculosis amongst the people than he has ever seen since that time. It has been asserted that intestinal putrefaction paves the way for intestinal infections, because putrefactive bacteria prepare the soil for the growth of pathogenic bacteria, and this has been utilised as an argument in favour of a pure vegetarian diet, eggs, cheese, and cow's milk being rejected because capable of encouraging the growth of dangerous microbes. Vegetable albumin is said to be less putrefiable than flesh proteins, and possesses the further advantage that it is always accompanied by at least three times its weight of carbohydrates. A remarkable commentary on this statement, which is bolstered up by concrete facts, exists in the practice of vegetarians taking large quantities of curdled milk. This, at

any rate, is the custom at Battle Creek, and one cannot help feeling surprised that with a low-protein diet, where there is stated to be practically no surplus of non-putrefiable vegetable albumin, there can be any necessity for the use of any means to neutralise the toxins of putrefactive organisms which have no obvious cause for existence. I cannot help looking upon such a system as a convenient excuse for the introduction of lacto-vegetarianism, because the lactic acid bacillus is only supposed to be of any value in protein decomposition, and is absolutely useless in carbohydrate fermentation—the probable evil in a fleshless system of diet.

An interesting commentary on these remarks, which were written and published more than a year ago, is to be found in a more recent pronouncement of Metchnikoff, who has discovered that lesions identical with those sclerotic changes produced by the phenols and indols of the fæces in man are also present in the horse and rabbit, which are unquestionably vegetarian. If this be so, then there does exist some justification for the use of curdled milk by vegetarians, on the assumption that the lactic acid bacillus inhibits the activity of the proteolytic bacteria, but the doctrine of intestinal auto-intoxication can no longer be utilised as an argument in favour of a fleshless diet, but of a well-balanced mixed diet.

Perhaps it is fortunate that, as has been demonstrated by Professor Walker Hall and Dr. W. A. Smith, a great many of the tablets used in preparing curdled milk are of no real value, the bacilli being quite unable to pass through the stomach safely, or even when they have done so, not being sufficiently active to overcome the fæcal bacteria. After a most careful and exhaustive examination of many of the lactic acid ferments on the market, they came to the conclusion that few of these were reliable, and that it was most difficult to determine this without a bacteriological examination, because the best acidifiers were by no means the best multipliers, and the amount of curd was by no means an index of the capacity of the organisms to pass through the alimentary canal.

Therefore, in many cases, much of the benefit ascribed to the curdled milk must have been owing entirely to the use of the milk as such, and incidentally the reduction or exclusion of more harmful liquids. There is, therefore, a great deal of doubt as

to the beneficial therapeutical influence of lactic acid bacilli, and it has been well summed up by Mendel in these words: “The usefulness of lactic acid, sour milk, and lactic acid ferments as curative agents is nothing less than problematical at the present moment.”

But whatever difference of opinion may be expressed on this point, it is absolutely certain that there is no indication for the indiscriminate and widespread use of curdled milk as a therapeutic agency. If the practice of moderation in eating and drinking be the keynote of the whole life; if a daily alvine evacuation be the rule—and this is by no means the prerogative of vegetarians—then we can afford to despise the much-advertised ravages of the putrefactive organisms in the colon.

CHAPTER XI

THE NO-BREAKFAST PLAN IN THEORY AND PRACTICE

THE principle of moderation, which is carried to excess in the practice of fasting, finds a certain form of expression in the various methods whose distinctive feature is the omission of one or more meals per day. The ostensible and loudly proclaimed object of such systems is somewhat forcibly to deprive the body of nutriment which is declared to be in excess of its requirements, and although all of them are in agreement on this point, they are at variance in the methods of applying the doctrine in practice.

The most aggressive section declares that one meal a day amply suffices for all the demands of the body, but we may at once dismiss this system as a freak, founded as it is on a misconception of physiological facts and on the dictum of Dr. Abernethy, who is reported to have said, "One-fourth of all a man eats sustains him; the balance he retains at his risk."

Most of the advocates of this method are vegetarians, and as they are compelled to eat a much larger meal than is customary, a much longer period is taken to digest and assimilate it than would be the case on a mixed diet. A certain amount of time may apparently be saved, but it must be at the cost of efficiency of work and even economy of food, for it is found that the body is unable to take full advantage of such a flood of nourishment poured into it at one time. In the end gastrectasis is bound to take place, on account of the mechanical power of the stomach being overburdened by the mere weight of food. At the best it is a system which should

only be adopted temporarily, and where this has been done we have known complete freedom to have been obtained from the most inveterate migraine, after every other therapeutical method had failed. This patient was a clergyman of massive physique, and he was accustomed to take his meal at midday, devoting an hour to the consumption of his victuals and a couple of hours thereafter to a python-like rest. As might be anticipated, this system has never succeeded in making any real impression on the popular mind, and the literature in support of it is very scanty.

Dewey's Crusade.—It is far otherwise, however, with the two-meal-a-day system, which has, as its corollary, the no-breakfast plan, because quite a number of books have been published dealing directly or indirectly with the method, and a selection of these both from medical men and laymen will be found in the bibliography at the end of the book. Its pioneer, the late Dr. E. H. Dewey, who has attained notoriety, if not celebrity, by the publication of his famous work on the subject, boldly proclaimed that the American people ate more than was good for them, and that most of their troubles could be cured by the omission of at least one meal per day. This announcement was hailed with acclamation by the diseased portion of the populace, and many adherents were gained immediately. The results attained were on the whole so beneficial that the practice of abstinence was carried to excess, and total desistence from food was by many persisted in for several days at a time. The evil effects resulting from this self-abnegation were so much less serious than had been anticipated that Dewey tentatively advanced the theory that the energy of the body is not derived from the food at all, but in some way spontaneously absorbed by the brain from some external source.

This, of course, is the echo of the theory maintained by theosophists and others, that nitrogen can in some occult way be obtained from the atmosphere and utilised by the body, perhaps in some manner analogous to its fixation by leguminous plants. Dr. Dewey quotes from Yeo's "Physiology" details of the estimated losses of the bodily tissues that occur in death from starvation. "Fat is at one end of the scale, and at the other the brain, which does not waste

till all the other textures and organs are depleted to the utmost.

Fat ...	97 per cent.		Spleen ...	63 per cent.
Liver ...	56 ,,		Muscle ...	30 ,,
Blood ...	17 ,,		Brain ...	0 ,,

(See also Chapter XV.)

"Instantly," says Dewey, "I saw in human bodies a vast reserve of predigested food, with the brain in possession of the power so as to absorb it as to maintain structural integrity in the absence of food or of power to digest it." "The head is the power-house of the human plant, with the brain the dynamo, as the source of every possible human energy." "The brain is not only a self-feeding organ when necessary, but it is also a self-charging dynamo, regaining its exhausted energies through rest and sleep."

These quotations will prove that Dr. Dewey began with the cautious assertion that the brain is a parasite living on the other bodily tissues, and ended by boldly declaring that it could charge itself during sleep. We can only infer from this that the body is capable of obtaining energy quite independent of the food, and his followers have not been slow in proclaiming that neither bodily energy nor bodily heat is in any way derived from the food.

Rabagliati on Energy.—In this country the chief apostle of this theory is Dr. Rabagliati, who in a number of books published during recent years, and again at the annual meeting of the British Medical Association in 1911, has maintained it against all comers. In his most recent book, as in most of his others, he has fortunately enshrined his ideas in such pedantic terminology that he has been, comparatively speaking, saved from much hostile criticism. Much of his reasoning is of a metaphysical order, which is quite beside the point in a purely physical subject, but when dealing with the ordinary facts of metabolism he quickly falls into obvious error. He quotes the case of a man who fasted for thirty-five days, and who lost in weight at most what amounted to 8 ounces a day. He adds, "According to accepted doctrine, even the starving man emits a caloric value of 2,000 calories a day in the form of heat lost. Now, half a pound of best rump-steak

provides energy if perfectly oxidised up to 547 calories. It is not to be assumed (is it?) that a man's general tissues will have a greater caloric value than an equal weight of bovine tissue." The questioning of his own assertion is a frank demand for information, and I do not hesitate to give it. I will pass over the fallacy that a starving man emits as much in a prolonged fast as 2,000 calories a day, and content myself with pointing out the mistake in his caloric calculations. He admits, with Dewey, that during starvation 97 per cent. of fat and only 30 per cent. of muscle is used up for the purpose of nourishing the tissues, or, in other words, three times more fat than muscle is used. Now, in every ounce of fat roast beef there are 155 calories, so that 8 ounces would mount up to as much as 1,240 calories; but as roast beef contains probably three times more lean than fat, it is reasonable to suppose that the half-pound of tissue material would yield much more than the 547 calories to which he refers.

Dr. Fraser Harris, in reviewing another of his books, asserts that to hold such a parlous view of the production of energy in the body is a tacit admission that Rabagliati does not understand the law of conservation of energy, nor believe in the power of the transmutation of various forms of energy into others. Heat, according to Dr. Rabagliati, is a "thing" which can be put into and let out of things, for, he says, "The heat itself was stored up in (by?) the sun long ago, and is now liberated by the action of chemical energy between carbon and oxygen," which is a denial that carbon oxidised by oxygen yields heat in a coal fire. Such fire ought to "burn" in a vacuum or in pure nitrogen, so long as heat was let out of it. Food does not contribute either to bodily energy or bodily heat, although it builds up the tissues of "growing bodies" and "repairs the waste," and is incidentally the source of all diseases. If bodily heat is not due to oxidation, why then do we inhale many hundreds of litres of oxygen in the twenty-four hours? Nitrogen, hydrogen, or any other gas would be equally suitable according to Rabagliati. The conclusion of this review is so apposite that I quote it in full: "Doubtless the fact that the temperature falls during sleep and that fewer calories are given off during sleep than during waking hours may, if 'viewed with insight,' support the

new view. Rubner and Atwater have lived in vain. This discovery is supplemented by the following gems. 'I should prefer the statement that all kinetic (or active) energy is probably warm to the statement that it is heat,' and 'Disease is nearly always, if not quite always, the process by which waste . . . is being thrown out of the body.' So that if we could only sleep enough and eat almost nothing, and throw no waste out of the body, we should be healthy. 'The food is in no sense the source of the working energy of the body, either mental or mechanical.' For what purpose, then, do cows, sheep, and horses eat so much and so continuously—are they too all mistaken, like the 'blind physiologists'? Ought they not also to fast and sleep? 'Many persons,' we are told, 'have fasted for six weeks or longer, and have experienced a positive increase of strength from the fast'! These comfortable facts cannot be well known to the 'unemployed,' else they would have obtained wider recognition. If only viewed with 'insight,' the condition of entombed miners and shipwrecked sailors, is, physiologically speaking, of all things the most desirable; if only their bodies would not waste, and they could sleep enough, they would be able, happy and warm, to live the simple life—an eternity of economy! Sidney Smith said the *Edinburgh* reviewers cultivated 'the muses on a little oatmeal.' The gospel from Bradford is that they would have done better spiritually, morally, and intellectually and mechanically if they had had less oatmeal and more sleep—and this in 1907!"

Clearly such a view of the production of bodily energy is absolutely untenable. But long before Dr. Rabagliati appropriated or conceived this view he was an advocate of a subsistence dietary, and in his whole-hearted pleading for its adoption he has ingeniously invented a perfect battery of most unrhythmical words, which at first sight have far from the illuminating function expected of them. He designates the taking of food as siteism, so that the one-meal-a-day system would be monositeism, the two-meal-a-day system disiteism, the three-meal-a-day system trisiteism, and so on. Pollakisiteism signifies the act of eating too often; polysiteism means eating too much; oligositeism means eating too little, and oligakisiteism eating too seldom. Modifications of these terms

are to be found in such words as pollakiamylism, signifying taking starchy food too often, and polyamylism, taking too much starchy food. It is questionable whether any good purpose is served by such a multiplication of compound words. Holding such views on the origin of physical energy, it is natural and obvious to conclude that as the body must be fully charged after sleep, no food would be required for some time thereafter. It is important to note, however, that the practice preceded the reasoning, which was only added as an afterthought.

The Fasting Headache.—But this is not the only erroneous physiological doctrine which emanates from the supporters of Dr. Dewey, for they boldly assert that normal hunger is never manifested in the stomach, but, like thirst, always in the glands of the throat and mouth. To account for the all-gone sensation in the pit of the stomach, which is usually associated with the desire for food, they declare that this is not normal hunger, which indeed has never been experienced from the days of infancy. The sensation usually felt is the abnormal craving of a morbid diseased appetite and the indication of a congested stomach. When, therefore, our stomach objects that it has not been supplied with its normal requirements in the way of breakfast, that is accounted for by suggestion and the sudden withdrawal of the stimulation produced by food. On the other hand, the headache which is the usual penalty of omitting our breakfast is due to the lack of withdrawal of its excess of blood for the purpose of digesting the ingested food, all unconscious of the fact that if this were the explanation the headache should have existed prior to the administration of food and be relieved by partaking of it.

Dr. Haig's explanation of this headache is equally interesting. He believes that the greater quantity of uric acid is excreted between 4 a.m. and breakfast-time, and that but for the intervention of this meal, usually containing large quantities of purins or xanthins, the excretions would continue. Should this meal be omitted, however, by those who are in the habit of consuming tea, coffee, and animal food, then a uricacidæmia is set up with all its ill-effects, of which headache is perhaps the most severe. Whatever truth there may be in this explanation, it is natural and consistent with his

theoretical views on diet; but presumably Dewey's disciples would argue that whether a person were living on a purin-free diet or not, the supervention of a headache would be likely to follow the omission of breakfast. Haig, on the other hand, teaches that headaches would not be likely to arise even on desisting from this meal, so that the theoretical explanation advanced by Dewey cannot be correct.

From the facts which we have adduced it is quite evident that the penalty for the omission of breakfast is not always the supervention of a headache, and when this does arise it is in most cases the manifestation of a "craving" for tea, coffee, or other toxic alkaloid. Every stimulation leaves behind it a residual impression. Continual repetition of the stimulation intensifies the impression, and tends to create a desire which can only be satisfied by an increase of the stimulus. The headache of tea-drinkers may be a congestion of the vessels of the cerebral cortex, which is only relieved by a repetition of the dose, or it may be some alteration of the neurones, necessitating readjustment. The subject is one still requiring much elucidation and is closely bound up with the physical explanation of habit. Pavlov asserts that "every food determines a certain amount of digestive work, and when a certain given dietary is long continued, definite and fixed types of gland activity are set up, which can be altered but slowly and with difficulty. In consequence, digestive disturbances are often instituted if a change be suddenly made from one dietetic regime to another," and this may very well depend on the secretion of gastric juice at the accustomed time. This is unquestionably the cause of the nausea and faintness often experienced, especially by women, when no food is supplied at the customary period, whilst in others, especially in men with a tendency to hyperchlorhydria, actual pain may arise.

The No-lunch Plan.—As an evidence that after all moderation is the most ideal system, and that the simple deprivation of breakfast is by no means the all-important feature, a new sect has arisen, the votaries of which, whilst approving of a two-meal-a-day plan, suggest that it would be much wiser to omit the midday meal, as there would then be not more than ten or fourteen hours between the times of taking

food, instead of six and eighteen hours, as in Dewey's method. This system is, however, categorised by Dewey's disciples as irrational, for the reason that in one of the intervals almost all the day's work is performed and all the energy expended, whereas in the other practically nothing is done. They declare that the division of the time is a purely arbitrary one, for the one half contains all the resting period, all the repair of tissue waste, and all the accumulation of energy, whilst in the other half there is practically no rest, all the expenditure of energy, and a continual breaking-down of the tissue elements. Forgetting their original statement that energy is only accumulated during sleep and in no way dependent on the supply of food, they advance the illogical contention that "an equal amount of food is necessary to supply the loss in both instances."

One would have thought that this admission was a complete avowal of the reasonableness of an early morning and a late evening meal, but there is evidently a confusion of thought in their argument, for they hark back to their original statement that as no energy is expended during the night, no work performed, no tissues destroyed, there can be no possible necessity for tissue replacement. The facts of physiology have been studied to little advantage by one who forgets the ceaseless work of the heart and great blood-vessels, the lungs, the muscles of respiration, and all the other factors contributing to the expenditure of energy in the internal work of the economy, which, though lessened during sleep, is only so in a minor degree.

But the internal work of the body is suddenly brought to the recollection of the disciple of Dewey by the natural desire of his body for its fresh morning supplies of nutriment, of which it is forcibly deprived because, forsooth, strength would be wasted by this untimely food in the stomach. The modicum of truth in this assertion is entirely nullified by his previous statement. Still, it is affirmed that if the denial of the body's demand for food be persisted in, then a clearer head, greater nervous energy, increased vitality and buoyancy of spirits will be the inevitable result. In every case without exception has this benign result happened, and never yet has one of Dewey's disciples apostatised. Such uniformity

of conduct seems very surprising in view not only of human nature but of human physiology, and as a matter of experience one constantly meets many who, though convinced of the value of the two-meals-a-day system, have found it intolerable to be deprived of their breakfast. This, of course, would not be remarkable amongst mixed feeders, but the cases to which I refer were almost entirely amongst the ranks of the vegetarians. Mr. Eustace Miles is a case in point. Converted to the two-meals-a-day system by reading Dewey's book, he relates that after two experiments he was compelled to give up the no-breakfast plan. As an alternative he partook of lunch between 10 and 11, and dinner between 4 and 5 p.m., and by this means succeeded in curing a persistent drowsiness which used to attack him for three or four hours in the middle of the day. His subsequent experience is of some interest, for he found that he was able to adopt the no-breakfast plan so long as his last meal on the previous day was not taken too early in the evening. Now, Dewey taught that it was essential that the two meals should be taken at 1 p.m. and 7.30 p.m. respectively, and although he resisted the insinuation, there is little doubt that as much food was taken at the two meals as would in the ordinary course have been consumed at the three or four which are now in vogue.

Clinical.—The man who takes a good breakfast and a midday meal as a rule eats very little at his two late repasts, and is therefore ready for a good breakfast. The man who takes a heavy meal at 7.30 p.m., especially if he be employed at a sedentary occupation, is quite unfitted for a heavy breakfast next morning. The secret therefore of the no-breakfast plan appears to lie in the unconscious adoption of the principle of moderation, so beneficial amongst the American nation, where the usual custom is to eat three or four heavy meals, including a particularly hearty breakfast of many courses. When, however, moderation is consistently practised there is no necessity for doing violence to the body by the withdrawal of what is to many the most enjoyable meal of the day.

At Battle Creek Sanitarium the two-meal-a-day system was in vogue for many years, but the three-meal-a-day system

has been substituted, and has been found in every way more satisfactory and hygienic than the old method.

Doubtless social habits and convenience are factors of greater importance in the regulation of our meals than scientific pronouncement. Barely two centuries ago breakfast was an unrecognised function in England, having originated in the practice of ladies taking an early dish of chocolate before rising. The chief meal was dinner, which, as in many country districts to-day, was eaten at noon, and this persisted until the spread of our industrial and commercial system and the enormous growth of cities made it necessary to introduce the system now in vogue. There is no doubt that two good meals a day are sufficient for most people, and in practice it is found that where a good breakfast and dinner are eaten, the lunch and tea are often ignored or replaced by a mere snack at the one and a cup of tea at the other.

"Whatever is true of other countries, the average man in this country finds that it is much better to take a good substantial breakfast, and most people find that they are incapable of very much work before it. A Highlander never faces the ascent of a mountain without a good meal in his stomach, and the late Dr. Milner Fothergill used to say: 'I would always back a good breakfaster from a boy to a game cockerel; a good meal to begin the day is a good foundation.' Whilst resident medical officer of a fever hospital, I was always advised by the visiting physician never to make a night visit to one of the patients without eating some food first, as quite a number of my predecessors had neglected this rule and succumbed to infectious diseases. I cannot vouch for the statement that the body is less liable to fall a victim to infection when there is a meal in the stomach, but I know that a late eminent surgeon used to look upon the inability to eat breakfast as the initial symptom of a breakdown."

It matters little whether the continental system of a light breakfast with early lunch and late dinner be adopted, or our own method of a heavier breakfast with light lunch about 1 p.m., and a late dinner about 6.45 or 7 p.m. All that is necessary is to eat just enough for the nutritive requirements of the body, and see that it is apportioned in such a way that it is not calculated to tax the digestive organs.

CHAPTER XII

RAW FOOD IN THEORY AND PRACTICE

THE outstanding feature of all dissent is partition. The type of mind which is favourable towards lack of conformity with the established order of things is just as apt to find points of dissimilarity and room for disagreement in its new sect. The fleshless feeder declares that the already used muscular system of a dead animal has lost all power of repairing the vital tissues of a living one—that in the highest sense of the term flesh foods are devitalised. On the other hand, he affirms with vigour that cereals, fruits, and nuts, being pure foods, are full of vitality which they are capable of transferring to those who consume them.

It does not require much reflection to see that the logical deduction from the claim that fleshless foods are pure, natural, and abounding in vitality, must be that they are therefore ready for use by man without the necessity for further preparation. The idea of eating flesh food raw is certainly repugnant, and so a militant section of the fleshless feeders triumphantly point to their viands, which are so natural that they demand no preparation, or perhaps it would be better to say, no cooking, to fit them for human consumption. Hence has arisen the sect whose disciples—with a lack of courtesy which, I will demonstrate, is not quite consistent with their practice—are known as “raw-fooders.”

This latest addition to the ranks of the so-called food reformers claims that its followers are hale, hearty, and happy on a diet which requires no cooking, and its study requires some attention, because it is vaunted as a remedy for

many ills, and is confidently regarded as a specific for stomach troubles. This assertion is so delightfully vague that it may signify anything, because the layman—and so far no medical support has been given to the raw-food idea in its baldest form—has an obstinate conception that the abdomen with all its contents is more correctly designated the stomach. But in addition to this potentiality it makes fat people grow thin and thin people grow fat, and ladies are specially directed to inquire into its miraculous powers of beautifying the complexion. The skin, in common with all the other tissues, is renovated, and the soi-disant raw-food scientist declares that under this system no waste matter can deposit in the cells, and so decomposed matter cannot roughen nor discolour the skin.

We are not surprised to find that the amount eaten by a raw-fooder at a meal is small, the reason advanced being that the stomach can “sense” just when it has had enough to satisfy the demands of the body. With cooked food, on the other hand, so much more is required because of the large proportion of waste matter it contains, that a “vast bulk of stuff” must be consumed before the stomach can be certain that it has done its duty by the body. This is solely (say the propagandists) because the life has been cooked out of the food by fire—not a bad thing for the consumer, one would say—and the physical energies are dissipated in their efforts to dispose of this huge quantity of waste matter foisted upon the unoffending organs of digestion. Being unable to cope with these demands, the body falls a prey to disease, which disappears the moment you join the ranks of the raw-fooders. Many other unwarrantable assertions are made in connection with this paradoxical dietetic system, but as they are unsupported by any evidence whatever, it is needless to repeat them.

A Residuum of Truth.—It cannot be gainsaid that there is something of real value in the notion, but something totally unlike the views advanced by its advocates. We may agree that, with other members of the animal kingdom, man originally partook of his food in the uncooked state, and it is highly probable that had he continued to do so, his evolution would have ceased at the troglodytic stage. Fruits, nuts, and

soft grains—or grains in the milky state, where the nutrient portion is in the easily assimilated form of dextrin and starch, instead of the more resistant starchy form of the ripe hard grain—comprised his staple diet, and we are quite cognisant of the fact that many people can subsist on just such a dietary to-day.

Just at this point it might be wise to interpolate the remark that, although the raw-fooder claims that his foods are “sun cooked” as well as uncooked, this does not signify that he employs no kind of preparation to fit them for the palates of his supporters. Were we inclined to press the point to its logical conclusion, it would be easy to prove that very few of the foods whose use they counsel have any claim to be included in the category of the uncooked. The term “cooking” is generally applied to all the processes by which food, as purchased retail, is prepared for the table, but it is more particularly employed in its restricted sense to describe the changes produced in food by the application of heat. If we consider the matter from the former point of view, we may well inquire what function is subserved by the manufactories engaged in placing the various raw foods on the market; but even if we waive the right to include that part of the definition and confine our attention to the latter portion, it is perfectly certain that heat in some form or other is resorted to in the preparation of many so-called unfired foods.

The system would hardly be a financial, still less a social success if people were left to select their food like the beasts of the field, and so electricity, transformed for the time being into thermal rays, is pressed into the service. Under this influence much of the crude starch is converted into dextrin, and although one hardly associates this with cooking in the usual sense of the term, because a coal fire has not been the medium of the thermal application, there is little doubt that up to a certain point the processes are identical.

Infantile Scurvy.—We know from experience that the prolonged use of cooked food to the entire exclusion of uncooked foods is invariably attended with impairment of the health and strength, and we are specially well acquainted with the ailment of infantile scurvy or Barlow’s disease, so called after Sir Thomas Barlow, who first clearly recognised

and defined it. The victims of this disease are pale and anæmic, suffer from extreme muscular weakness, on account of the tenderness of their lower limbs, cry loudly when much handled, and display sub-periosteal extravasations of blood and other evidences of escape of blood from the circulation. There is a general consensus of opinion that this condition is produced by the use of cow's milk which is not perfectly fresh or has been subjected to the action of heat. Whatever changes have taken place—whether some occult or yet unisolated substance has been driven off or the lactic acid bacilli have been destroyed—it is quite certain that the milk has lost something to which it owes its indispensable qualities of freshness. To bring about a speedy recovery it is only necessary to use fresh milk, although this may be supplemented by raw meat juice or fruit juices, all of which possess anti-scorbutic properties in a high degree. In any case, raw food of some easily assimilable kind must be administered before the cure can be completed.

An analogous condition of affairs is sometimes seen in adults suffering from typhoid fever, who are kept too long on gruel, broths, or other cooked foods, and the addition of fresh fruit juices, such as oranges, or of whey, or even buttermilk, may be relied upon to counteract this malign influence.

Diarrhœa and Constipation.—The disease, however, of all others which owes its inception to cooked food is that terrible autumn epidemic, diarrhœa. Vincent says: "It is essential for the development of the disease that the characteristic properties of the natural food of the infant should have been destroyed by heat, by preservatives, or some other means." Milk left to itself soon curdles by virtue of the lactose being converted into lactic acid by the lactic acid bacillus. Such milk creates digestive disturbances in infants, but this differs from zymotic enteritis in the absence of the toxæmia which is the characteristic and fatal feature of the disease. Raw milk which has soured is easily detected, and need not be used, but even if so, the lactic acid bacillus prevents the development of changes of a poisonous character. The cause of zymotic enteritis, he declares, is the toxins produced by the ordinary organisms of putrefaction, which can only grow

in milk in which the lactic acid bacillus has been destroyed by the application of heat or some other agency. To prevent the disease, therefore, he insists on a supply of pure raw milk being placed within the reach of every family.

It is well known that boiled milk is much more constipating than fresh milk, and it may be that this is due to the destruction of its contained lactic acid bacillus. This is hardly likely, however, as with many people curdled milk is quite as constipating, and it is probable we must look to some change in the caseinogen, or its large content of calcium, to account for the constipating qualities. There is no evidence that boiling in any way impairs the nutritive qualities of milk or any other food, although cooking produces profound changes in their character. A ripe raw apple possesses a sweetish flavour with just a sufficient suspicion of acidity to commend it to the taste, but the same apple stewed or cooked becomes so acid that it may require to be deluged with sugar before it can be eaten. This is a peculiarity of most fruits, that they taste much better raw than cooked, and may be an indication that the natural method is to eat them in the raw condition.

It is also certain that they are much more easily digested in that condition by the majority of people, and it has been asserted that they contain enzymes in the form of oxidases and diastases from which the body may derive benefit and which are destroyed in the process of cooking. If this could only be demonstrated, it would be an infinitely more satisfactory argument in favour of raw food than the frequent reiteration of the elusive element of vitality, a property which it is absolutely impossible to define. The increase of acidity suggests that some volatile alkaline ingredient has been driven off by the application of heat, which would serve to neutralise the harmful acid ingredients or render them more tolerable to the body juices. It may be, indeed, that some valuable natural chemical salt is decomposed, and that in this way the body is being robbed of some essential nutrient.

Raw fruit is therefore more appetising than cooked fruit. It does not follow, however, that raw flesh is in the same position, although the raw-fooder, and with him the flesh-feeder, would assert that the development of agreeable flavours

in meat by the process of cooking is an unnatural pandering to a depraved appetite. Cooked meat is said to take longer time to digest than raw meat, but this is quite inexplicable on the hypothesis that agreeable flavours which encourage a flow of gastric and other juices are developed by the cooking process. In any case it is a certainty that cooked meat is much more easily masticated than similar meat in a raw state, and this is obviously advantageous when we reflect that in the case of meat the only function subserved by mastication is that of comminution, as it contains no element upon which the diastatic power of the saliva can be exerted. It is no argument against the use of flesh as a food to say that it requires cooking, for custom and instinct alike demand that most fleshless foods be rendered agreeable and more digestive by the process of cooking.

Changes effected in Food by Cooking.—Much more suitable arguments at the command of the advocates of a raw diet—at least when they are reasonably applicable—may be found in the undoubted facts of ease of preparation and economy, for both time, trouble, the wages of a cook and the cost of a fire are saved when the food simply requires cleansing to prepare it for consumption. But the plea of economy may be advanced from the other point of view, that a certain percentage of waste is inseparable from the process of cooking; for here we leave the realm of theory and entrench upon that of indubitable fact.

During cooking by the ordinary methods meat loses from 10 to 50 per cent. of its original weight, and although the loss consists mainly of water, both protein and fat contribute their share. A small proportion of the proteins undergoes obscure chemical changes of such a nature that gelatin, nitrogenous extractives, and other substances are produced, and these tend, however slightly, to reduce the nutritive value of the food. Grindley has shown that when meat is cooked in water at 80°–85° C., it matters little whether it be first placed in hot or cold water, thus shattering a widespread belief that it is essential to plunge it at once into boiling water if we desire to prevent the escape of its nutritive juices. In a series of ninety experiments the average loss of protein was 7.25 per cent., being always greatest when the meat was cut

into small cubes and cooked for a very long time, and least when a large fat piece of meat was cooked for over two hours.

The loss of fat depends more upon its quality than its quantity, and varies from '6 to 37·4 per cent., the average being 11·7 per cent., and the greatest loss being incurred when the temperature was highest. On the other hand, during experiments on roasting, the loss of fat was very much higher, averaging as much as 34·27 per cent., while that of protein was much lower, amounting on an average to no more than 1·97 per cent. As might have been expected, the higher the temperature and the longer the process was continued, the greater was the loss both of fat and protein, while the larger pieces lost relatively less both in weight and nutritive value than the smaller pieces.

These experiments are doubtless of comparatively little interest to the "raw-fooder," who naturally but seldom includes meat in his diet list, and they have less influence as an argument in favour of the system than those about to be recorded.

During the cooking of vegetables in water the cellulose absorbs water, becomes softer and more easily masticated, and although probably no more digestible, is at least more likely to be attacked by the bacteria in the alimentary canal. The rupture of the cell walls, however, exposes the starch granules to the action of the water, and hence they become swollen, deformed, and more digestible. As, however, all the nutrients in vegetables are not always enclosed in the cells, but in a varying degree exist in solution in the juice, a large proportion of these soluble substances is liable to be lost when the vegetables are cooked in water. This applies especially to the sugars and valuable mineral matters, and even the starches, though insoluble, suffer a certain amount of loss mechanically. The soluble proteins, on the other hand, are coagulated by heat, and are thus to a certain extent conserved; but when the soaking process is conducted in cold water, a large percentage is thereby lost. Hence the advantage of cooking vegetables, where practicable, with the skin on, and where this is impossible, of submitting them to the action of steam, for by these methods the loss is immensely reduced, being in most cases less than 1 per cent.

Some idea of the loss sustained may be derived from a reference to the experiments of Snyder, Frisby, and Bryant. They found that when potatoes were peeled, cut into pieces and soaked in water before boiling, half the total nitrogen—including a quarter of the proteins—was lost. When cooked immediately after immersion in cold water, the loss was three times less, and when plunged at once into boiling water and then cooked, six times less. This last method is not recommended, as some kinds of potatoes are spoiled in the process.

Carrots which had been scraped, cut into pieces and then boiled, lost from 20 to 40 per cent. of the total nitrogen, and 15 to 26 per cent. of the sugar, depending upon the size of the pieces.

Thirty to 40 per cent. of the dry matter of cabbages, including one-third of the total nitrogen and carbohydrates, is lost during the process of cooking, and more than 80 per cent. of the carbohydrates of onions and turnips disappears during boiling.

The lesson to be learned from these experiments is that from the point of view of economy it is judicious to eat vegetables in salads or in soups, where, of course, all their valuable juices are retained, or where they must be cooked in bulk, to utilise one of the many steam-cookers now so fashionable.

It has been stated that all foods contain substances which are injured or destroyed by the application of heat in cooking, and lecithin, which is of such importance in the growth of tissue and blood cells, has been particularly cited as a case in point. But this is certainly overstating the case, because the addition of fresh fruit juices—which contain no lecithin—is alone necessary to nullify the evil effects of subsisting on cooked foods. In the case of scurvy even these are not essential, for provided that fresh meat be supplied, even although it be cooked, the disease will soon vanish under its benign influence.

It has been averred that a raw-food dietary would prevent the appearance of auto-intoxication with all its evil accompaniments, mainly because it would necessarily compel the total exclusion of animal proteins, which are much more readily

attacked by putrefactive organisms than vegetable proteins. It is a strange corollary to this statement that milk previously sterilised should be employed as a medium for the conveyance of the counteracting beneficial organisms.

Limits of Hygienic Utility.—Whatever the elusive factor may be which constitutes the freshness of a dietetic article, it is to be found in the juices not only of fresh fruit, but also of raw meat and uncooked vegetables. Raw meat juice separated from the solid proteins will not only prevent tuberculised dogs from succumbing to the disease, but will enable them to remain in robust health, whereas when fed on muscle fibre minus the juice, even to the extent of 2 or 3 pounds daily, they quickly collapse. A piece of raw cabbage inoculated with human fæces and placed in an incubator at the temperature of the body inhibits the growth of putrefactive organisms, whereas in a cooked cabbage in similar circumstances the number of putrefactive germs increases enormously. This would suggest that raw foods are capable of exercising a wholesome influence in the alimentary canal, by inhibiting the development of toxins readily generated there by the action of germs upon cooked foods.

On the other hand, on account of the large content of cellulose they are by no means easily digested, and probably in this reason lies the value of raw foods more than in the mysterious factor of vitality. In the nutrition of the carnivora and omnivora cellulose is of minor importance, whereas the herbivora obtain quite a considerable proportion of their carbohydrate in the form of cellulose. As it is believed that none of the digestive fluids are capable of dissolving cellulose, it is requisite for us to consider the mode in which it is likely to be prepared for utilisation by the body.

Celluloses.—Celluloses are divided into three classes, according to their behaviour with reagents: (1) those like cotton fibre, which offer a maximum resistance to hydrolytic action; (2) those usually called oxycelluloses, which are less resistant to hydrolysis; (3) those which are more easily hydrolised, with a formation of carbohydrates of low molecular weight. The cellulose of the walls of the cells of seeds is an example of this class, and it is easily decomposed

by acid and more or less soluble in alkalis. Allied bodies called pectins may be obtained from the juices of many fruits, and are the cause of the congealing in jellies.

In nature pectins and cellulose are broken down either by the enzyme cytase, which is not an ingredient of any known digestive juice, but is secreted by the cells themselves, and by various organisms, or by decomposition in the open air through the action of certain bacteria and moulds, or still further by fermentation under anaërobic conditions through the action of specific bacteria. It is this last-mentioned method which is of interest to us, because by just such a process cellulose can be broken down in the alimentary canal into carbon dioxide, methane, and such fatty acids as acetic, butyric, and valeric. It is known that cellulose does undergo some transformation in the bowels, because it is impossible to recover from the fæces the whole amount introduced in the food. Tappeiner has been able outside the body to dissolve as much as 70 per cent. of cellulose by means of the intestinal juices of the horse, which are rich in bacteria.

It is reasonable to suppose that something of the same kind takes place in the body, or that the cellulose is acted upon by the epithelium of the intestinal canal. The human intestine can dissolve a part of the tender cellulose of young vegetables, as much as 40 per cent. of the cellulose contained in them being unrecoverable in the fæces. It is quite possible that the valuable mechanical irritation produced by cellulose on the intestine is to a large extent lost when foods which contain it are cooked, and that in the uncooked system which we are considering the more efficient evacuation of the bowels which is likely to be present frees the body of toxins which would otherwise be absorbed.

But it must not be forgotten that these are just the circumstances in which excessive fermentation of carbohydrates is liable to take place, and this, of course, constitutes an important source of loss of potential energy in the diet through the conversion of the sugar or starch into carbon dioxide and the various acids mentioned above. Major McCay describes the effects of such a process in Bengali prisoners and others who, because of excessive intestinal fermentation, suffer from

flatulency, tendency to diarrhoea and colic, and are accustomed to excrete faecal matter soft from admixture with gas, and light brown to yellow in colour for the same reason.

Schmidt has ascertained by personal observation that sufferers from chronic constipation are quite capable of utilising both raw and cooked vegetables; and even mushrooms, which are the most resistant of all cellulose-containing plants, are completely disposed of. This is due to some agency at present unknown, because when constipation is induced in a normal healthy subject his coefficient of assimilation is not increased. There are, however, perfectly normal individuals who are able to assimilate raw vegetables, and these are true vegetarians or herbivora, whereas those who are unable to utilise them he designates carnivora. He has demonstrated that the more marked the gastric acidity the more vegetable matter is digested, and this is due to the solution of the cement between the cell walls, which is composed of pectins and hemi-cellulose. This process is strictly comparable to the digestion in the stomach of the connective tissue between the fibres of meat.

Nor must we lose sight of the fact that raw starch is by no means easily digested. Whether it be administered in potatoes or cereals, only a very small portion of raw starch is capable of assimilation. It is therefore passed in the stools and has a very deleterious effect on the digestive processes. In starch manufactories certain of the employees become addicted to the habit of eating the starch, and rarely survive longer than a year. Profound disturbance of the organs of digestion and assimilation ensues, malnutrition supervenes, and intense anæmia—which is the objective of the unfortunate victim in her desire to obtain a more interesting if not more attractive complexion—becomes established before the fatal *dénouement*.

Where the organs of digestion are already impaired the use of uncooked foods is by no means free from danger, and even when the digestion is good it is wise to give special attention to their careful mastication. I have seen more than once a most severe attack of acute dyspepsia arise in a subject of diminished gastric motility from eating a raw apple or other form of raw fruit. In any form of atonic

dyspepsia all uncooked foods should be reduced to a liquid or pasty state in the mouth before swallowing, and any insoluble fibrous or other solid particles should be rejected.

Fruits in the ordinary acceptation of the term may be divided into two classes: (1) food fruits, some of which, like the fig, contain a fair percentage of protein; (2) acidulous watery fruits, containing from 75 to 95 per cent. of water, practically no protein or fat, from 25 per cent. of sugar in some grapes to 1 per cent. in lemons, and pectins which exert a demulcent effect on the bronchial mucous membrane. The valuable therapeutical influence of fresh fruit juices on the body is mainly due to citric, malic, and tartaric acids in combination with alkalis. These acids are converted into carbon dioxide in the organism, and the bicarbonate of potash thus formed is a potent alkalinising agency, all the more powerful because it is present in a nascent state. The alkali contained in a kilogram of strawberries is, according to Linossier, equivalent to 9 grams of sodium bicarbonate. The explanation of the valuable properties of raw fruit as compared with cooked fruit is that its mineral substances are combined with organic matters forming colloidal compounds. Most fruits have a diuretic action, partly due to the potash salts and partly specific, and in addition uncooked foods, both fruits and vegetables, possess the estimable quality of leaving a large indigestible residue in the bowel, which stimulates intestinal activity, hastens the movement of the intestinal contents, and so tends in a natural manner to lessen the inception of putrefactive processes. For short periods of time an inclusive diet of raw food may be adopted with benefit. The grape cure, the whey cure, the sour milk cure, the apple or exclusive fruit cure, are all occasionally of undoubted therapeutical value. Medical supervision for the patients undergoing these treatments is absolutely essential if beneficial results are to be obtained, and, needless to say, prolonged adherence to any of them is to be strictly avoided.

Moreigne has investigated the action of the grape cure, which consists in eating from one to six or even more pounds of grapes actually gathered from the vine itself. He reports that the urine is increased in quantity, is clarified, becomes

less acid, and, as might be expected, considering no other food is eaten, contains much less uric acid. The chlorides and other mineral constituents are increased in quantity, despite the fact that the grapes contain no chlorine. Glycosuria never takes place, even although as much as 600 grams of lævulose and glucose may be ingested daily; the weight increases and the appetite improves. The grape cure is recommended for the treatment of constipation, hepatic congestion, abdominal plethora, hæmorrhoids, gout, gravel, and certain skin diseases. Raisins or even sterilised grape juice make a fairly effective substitute. A lemon cure is also in vogue for the treatment of rheumatism and gout, but this only requires the addition of from six to ten lemons to the diet each day for ten days or a fortnight.

No observations by reliable investigators have been published which demonstrate the value of living exclusively upon a raw dietary. The nearest approach to such a study was that made by Professor M. E. Jaffé, of the California Agricultural Experiment Station. His observations were confined to the "fruitarians" of his own State, and he gives the following as a sample day's rations: apples, 475 grams; bananas, 110 grams; oranges, 850 grams; dates, 5 grams; olive oil, 10 grams; almonds, 55 grams; pine nut kernels, 70 grams; and walnuts, 50 grams—1,325 grams (nearly 3½ pounds) in all, containing 62 grams of protein and 2,493 calories of food value. He was satisfied that no more effort was required to digest the fruit and nuts in those accustomed to them than is required for milk and bread. There was, however, no attempt made to subsist on absolutely uncooked food, and in any case the standard of physical fitness produced by the system was not on a very high plane.

English fruitarians interpret the system on a much more liberal principle, as is evidenced by the following sample of a day's feeding:—

Breakfast.—Porridge and honey or bread and milk, toast and butter with a little vyttale or olive oil, a dozen raisins (stewed), an apple, and a few nuts, a small cup of cocoa.

Dinner.—Potatoes and greens and butter, with an occasional fried egg, a milk pudding, or a little cheese and salad and oil, half a glass of water.

Tea.—A cup of cocoa, a slice of bread and butter, and a piece of currant cake, or jam, or fruit salad.

Supper.—Bread and milk or cold rice-pudding with raisins, or bread and cheese with a glass of hot milk or oatenade (rolled oats simmered in milk and strained).

As might be expected, the results of living on such a system are much more satisfactory, and all experience goes to prove that recovery from disease is best brought about by the most careful attention to the cooking of the majority of food-stuffs, although the inclusion of a moderate but regular allowance of uncooked vegetable and fruit juices is often advisable and would frequently hasten convalescence.

The ordinary healthy man should have no difficulty in taking some raw fruit or vegetable with each of his daily meals—a banana, apples, or orange with breakfast; lettuce, tender asparagus, celery, pineapple with dinner; French plums, nuts, radishes with other meals. By this means he will obtain all the advantages, and none of the disadvantages, of uncooked food.

Any virtue in the raw-food theory lies entirely in its incentive to moderation. The very nature of the food suggested, however agreeable it may be rendered by its mode of preparation, is hardly conducive to overeating. Besides, it contains such a large quantity of ballast, or insoluble and indigestible material, that much less of it is absorbed into the circulation to become available for metabolic purposes. Hence there is less risk of supplying excessive quantities of nutriment to already overburdened organs.

The valuable quality of freshness has been over-emphasised, as if it were the only factor of importance in food. It would be quite as rational to say that because sugar is an excellent means of supplying the body with heat and energy, therefore we should confine ourselves to an exclusive diet of sugar. If, however, it succeeds in attracting attention to the estimable qualities of fresh fruit as an item of the daily menu and the equally valuable virtues of fresh vegetables, it will have effected a great service for civilised mankind. The conservative method of cooking vegetables so as to retain their fresh juices is capable of greater extension in this country, and we may well learn a lesson from France in this connection.

CHAPTER XIII

YEAST-FREE BREAD IN THEORY AND PRACTICE

YEAST has been used in the manufacture of bread probably from prehistoric times, for certainly it was known to the Egyptians two thousand years before the Christian era. Its claims to recognition as an almost essential item in bread-making are therefore time-honoured, and until recent years no suspicion with reference to its hygienic position has ever been whispered. It could hardly be expected, however, that it could escape attention for all time, and so in common with practically every ingredient of the daily menu it has been impugned as a deleterious substance.

Is Yeast a Malign Agent?—It is categorically stated to be a putrefactive ferment, which, when used in bread, tends to continue the “putrefactive fermenting” process in the alimentary canal of the consumer, and is more or less productive of blood-poisoning, which may develop into and aggravate disease. A certain section of “food reformers,” therefore, not altogether but mainly composed of vegetarians, is satisfied to subsist upon yeast-free bread, which, whatever its merits, lacks most of the attractions usually associated with the staff of life. The disciples of this sect maintain that “the digestive ferments and alcoholic ferments are opposite in character, the action of the former being a decomposition for the purpose of recomposition, and of the latter, a breaking up into ultimate products which are then suitable only for resolution as manurial elements.” They contend that it is a fallacy to suppose that yeast-raised dough, when cooked, has all its yeast activities destroyed, but certainly the article in the *Lancet*

(April 10, 1909) on which they rely for support in no way corroborates them. The writer of this article, in drawing attention to the amount of alcohol in hot cross-buns, points out that each bun, weighing two ounces and a half, contains 7.2 grains, or .68 per cent., of alcohol, equal to one-third of a fluid ounce of light beer, so that twenty buns would contain as much alcohol as a tumblerful of beer measuring 8 ounces. The presence of the alcohol is unquestionably due to the fermentative action of the yeast, the tenacious character of the dough, and its external albuminous glaze preventing its dissipation by the heat during baking.

No reference whatever is made to the continued activity of the yeast, but, even if this had been established, it would have been quite unfair to infer that bread would betray the same deficiencies, because the influence of the heat acting on a less tenacious dough, with a more permeable covering, is quite sufficient to ensure the destruction of most of the yeast and the evaporation of any alcohol which may be formed. Hence well-baked bread never displays on analysis anything but the merest traces of alcohol, to which even the most bigoted teetotaller need make no objection.

The virtues of this bread, however, do not terminate with the exclusion of yeast, for, like its allied products, such as cakes, biscuits, &c., it is salt-free, nor is any chemical substance whatever permitted to be added during its manufacture. Furthermore, nothing but the entire wheat grain, free from husks, and ground so finely that it is incapable of irritating the mucous membrane of the alimentary canal, is used. And to complete the list of its good qualities, it is mixed with distilled water.

The Baking of Bread.—It is impossible to appreciate too highly the extreme solicitude on the part of the manufacturers that nothing but the purest of materials should be employed in their products, and they deserve a high meed of praise for their spirited effort in the service of the public, but, apart from the performance of this important duty, it is questionable whether their action is not founded upon a misapprehension. In order that we may form a true estimate of their claims, it will be necessary for us to glance for a moment at the problem of bread-baking. Flour cannot be eaten uncooked.

To utilise it as food it must be cooked, and for this purpose all that is necessary is to mix it with water, mould it into a definite shape, and bake it. This will be recognised as ship's biscuit, a substance difficult to masticate and hence to digest. When spread into thin flat cakes, usually perforated, it is known as unleavened bread, and in this form is more easily digested, because more capable of being thoroughly masticated.

For the purpose of making bread it is essential that the mixture of flour and water, which is a tenacious viscid mass, should be interpenetrated by a gas of some kind, and it was discovered that this could be effected by mixing the dough with yeast cells and setting it aside in a warm place. Like many other micro-organisms, yeast cells are practically ubiquitous and capable of floating about in the atmosphere, looking about for a suitable soil upon which they may settle and grow. As this is usually a saccharine medium, the yeasts are generally known as *saccharomycetes*, and whenever they get a chance they develop with remarkable rapidity and produce a number of chemical changes, the most important amongst them being fermentation. When the yeast cells deposit themselves in dough left exposed to the air, bacteria of one kind or another likewise gain admittance at the same time. Hence both grow in the mixture of flour and water, extracting their nutriment therefrom, the yeast subsisting upon sugar, throwing off carbonic acid and alcohol as by-products, the bacteria in the same manner producing lactic and acetic acids. This mixture was called leaven, and its product leavened bread, a sour tasting and smelling substance with various drawbacks, quite corroborating many of the allegations made by the yeast-free advocates.

But it is now abundantly possible to obtain pure yeast prepared in a special way and purified by repeated washings, a much more active, agreeable, and wholesome substance than the old-fashioned leaven. Under certain circumstances, which need not here be specified, this yeast attacks with avidity the small proportion of sugar in the mixture of flour and water and multiplies with great rapidity, each molecule of sugar being converted into two molecules of alcohol and carbonic acid gas respectively. This gas fills up the dough with bubbles, which

make it light and spongy, and when baked in an oven for one hour and a half at a temperature of 450° F. the bubbles of gas expand still further, the fermentation ceases because the yeast cells are killed, and bread is formed. In addition to killing the yeast cells, the excessive heat volatilises 71.2 per cent. of the fats, and about 8 per cent. of the starch on the outside is rendered soluble or converted into dextrin.

A large percentage of the carbonic acid and also of the alcohol is driven off, although quite 16 grains of the latter is contained in each four-pound loaf. A certain amount of the flour, therefore, has been wasted, and, besides the fat already mentioned, it is computed that 1.3 per cent. of the protein and 3.2 of the carbohydrates, or altogether 5 per cent. of the total caloric value, has been lost.

It is perfectly justifiable to promote efforts for the prevention of this loss of nutritive material, and besides the method under discussion, two others have been suggested. In the one case, air is forced under pressure into the dough, the bread, thus called aerated, being baked thereafter in the usual way. The result is quite successful, but for some reason—probably a somewhat insipid, uncooked taste—this bread has never been very much in favour. In the other, a baking-powder, consisting of an acid and alkaline carbonate, generates carbonic acid gas when water is added, and if thorough admixture with the dough has taken place, a perfectly sufficient aeration of the dough ensues. The objection to this method consists in the gratuitous importation of chemical substances, the daily consumption of which may in the long run be prejudicial to the best interests of the body.

There was a delicious comestible called a soda scone, of which I was accustomed to partake freely in my boyhood's days in Scotland, and I am not altogether sure that it did not aggravate a dyspeptic condition due to hyperacidity from which I then suffered much. Its peculiarity resided in the fact that it was home-made, the flour being mixed with milk and water, or skim milk alone, and baking-powder—consisting of an impromptu combination of tartaric acid and an excess of bicarbonate of soda—the product being rolled out into circular cakes and baked on a gridiron or "girdle" (griddle), as it is termed in the North. The excess of alkali was sufficiently

strong to be tasted, and the general impression is—although it is hardly corroborated by Pavlov—that small doses of alkali, whatever their transient effective powers of neutralisation, only stimulate a further outflow of acid. In any case, bread made in this way is not at all popular, and whether from laziness or preference the public demand baker's bread.

Nor is this at all surprising, for from every point of view, despite the serious indictment of the yeast-free sect, the normal commodity or article is to be preferred. Where pure yeast is employed, or even where there has only been a negligible contamination with bacteria, the baking of bread should destroy both bacteria and yeasts; but unless the full conditions be complied with, and especially unless a sufficiently high temperature be applied for a sufficiently long space of time, the moist interior may not be reached effectively, and some of the micro-organisms may not be killed. It is quite possible to obtain yeast cells from the interior of what is termed slack-baked bread, which will grow with a vigour competent to raise fresh dough. Bread should always be thoroughly baked, and when the process is completed, and it is removed from the oven, it should be cooled as quickly as possible. The practice customary among some domestic cooks of covering the freshly baked loaf with a thick cloth to retain the steam, in order that it may soften the crust, favours the continuance of the germ growth within the loaf.

The Beneficial Effects of Yeast.—No harm need, therefore, be anticipated in an ordinary way from the dead yeast cells in properly baked bread, and even although a few live ones are encountered, they are more than likely to have a beneficial influence. Combe concludes his dissertation upon yeasts with this statement: "The yeasts are microbicidal, they attenuate the toxins, augment the number of phagocytes, and favour intestinal peristalsis—qualities which must render them useful and valuable in exaggerated intestinal putrefaction and consequently in digestive auto-intoxication." Brewer's yeast, he declares, is an "energetic antiputrefactive medicine," and is consequently of great value in gastric dilatation with exaggerated fermentations where there is not prolonged retention. It is likewise of value in acne, furunculosis, urticaria, &c.—diseases which are in some measure associated with the

absorption of toxins from the alimentary canal. In any case, as the yeast cell is ubiquitous, even the consumer of yeast-free bread must be exposed to its action, and so would be subjected to the same risks of "blood poisoning which may develop into and aggravate disease"—quite a gratuitous declaration after the distinguished authority I have just quoted.

Ferments and their Action.—This does not, however, dispose of the statement that the action of the digestive and alcoholic ferments is quite opposite in character, nor can I see how this contention can be upheld. Ferments were at one time divided into those which were structureless, lifeless, amorphous substances, termed enzymes, and those which were living organisms with a definite structure. To the former class belonged all the digestive ferments, such as diastase, maltase, amylase, &c., and to the latter such substances as yeast. It was then considered that their mode of action was essentially different, although their ultimate results were similar or identical. It is now known that organised ferments are simply a residence for the unorganised ferments, and that their action is entirely dependent on the latter, although there is no sharp line of demarcation between individual cell-ferments and the free unorganised ferments. It is recognised, however, that there are decided differences between them, as for example, that the organised ferments are easily destroyed, being killed by oxygen under pressure, and rendered inoperative by a temperature of 100° F., while many antiseptics, *e.g.*, salicylic acid and chloroform, paralyse their activity. Unorganised ferments, on the other hand, are not affected in their action by chloroform, and resist when dry a much higher temperature, although in solution they are decomposed quite as easily as their organised allies; but probably these differences are more apparent than real, and owe their origin to the accidental circumstance of association with living protoplasm.

Fermentation has been defined as the chemical change produced by the agency of protoplasm, or of a secretion prepared from it, the former class being exemplified by the lactic acid fermentation of sugar and the acetic acid fermentation of alcohol, whilst the alcoholic fermentation of sugar is a typical example of the latter class. By mixing brewer's yeast with

quartz, sand, and infusorial earth, grinding the resulting mass and subjecting it to a pressure of 400 to 500 atmospheres, Buchner was able to extract a substance called zymase, which could decompose sugar into carbonic acid and alcohol. It is perhaps more correct to say that the liquor expressed from yeast contains the enzyme zymase, an unorganised ferment which is responsible for the alcoholic fermentation. As this yeast juice is difficult to prepare and rapidly loses its activity on standing, a preparation termed zymin, or permanent yeast, is now used, which will retain its active properties for a prolonged period. It is a dry powder, consisting of yeast cells which have been killed by contact with ether-alcohol or ether-acetone, but still containing the active enzyme (zymase).

The yeast cell contains several ferments, amongst them being invertase, an enzyme capable of passing through the cell wall, and thus termed an extra-cellular enzyme, in contradistinction to maltase and zymase, which are intra-cellular, as they can only be obtained by breaking down the cell wall wholly or partially. Maltase and invertase are identical with the normal digestive ferments of the same name. In addition to this, however, the liquor expressed from the yeast cells contains a ferment called endotryptase, whose action quickly counteracts and destroys zymase.

In spite of much careful research, very little is yet known of the ferments or, as they are now more usually designated, enzymes. Information is, however, being slowly accumulated which tends to relate them to the proteins, and the following outstanding facts regarding them and their effects are worthy of mention :—

(1) Their activity involves no change in themselves, and an absurdly attenuated quantity can repeat the same reaction over and over again. It is known that invertase can invert 200,000 times its own weight of cane sugar and rennin double that quantity of casein. (2) Their action is by no means unlimited, because in course of time a gradual loss of efficiency betrays itself. (3) Their operations are absolutely specific, fats, carbohydrates, and proteins being acted upon by distinctive enzymes capable of effecting changes in themselves alone. The nature of the reactions are inferred from the end-products, which are in most cases recognisable. (4) For the most part ferments are

produced in the body by living cells, some of them being retained in substance of the cells for their own personal ends and others expelled for purposes directly or indirectly to benefit them. (5) Ferments have many analogies with toxins. Injected subcutaneously, they act as poisons, producing a rise of temperature and finally death, while, as we have seen, anti-ferments can be formed in the same way as antitoxins.

It is now known that micro-organisms do not effect their deleterious action upon the body *per se*, but through the medium of their exudations, and as these are mostly of the nature of enzymes, the germ theory of disease itself is closely bound up with fermentation. Many of their products, such as ptomaines and toxins, are of the most poisonous character, and it is interesting to know that while the former are alkaloidal, the latter are proteins with no really essential chemical differences from those which are useful as foods.

The enzymes may be classified as:—

- (1) Hydrolytic, including those which induce the substance on which they act—termed the substrate—to combine with water before disintegration. All the digestive enzymes are of this character, and these may be arranged as follows:—(a) amylolytic or saccharolytic, which convert polysaccharides into dextrose, *e.g.*, ptyalin, amylopsin; (b) inverting, which convert disaccharides into monosaccharides, *e.g.*, invertase, maltase, lactase; (c) lipolytic, which split fats into fatty acids and glycerine, *e.g.*, lipase; (d) proteolytic, which split proteins into proteoses, peptones, polypeptides, and amino-acids, *e.g.*, pepsin and trypsin; (e) peptolytic, which split proteoses and peptones into polypeptides and amino-acids, *e.g.*, erepsin.
- (2) Oxidising ferments, *e.g.*, oxidases, which are mainly intracellular and oxygen carriers.

Other excellent examples of intracellular enzymes are to be found practically in every cell, and are intimately associated with metabolic changes in the protoplasm. Their action is chiefly digestive in character, and as their activity continues after death, they are responsible for autolysis when the

tissues are kept in an aseptic condition and at an appropriate temperature.

Observations on the cells of many secreting organs disclose little granules, which are really the precursors of the enzymes, hence called zymogens. Many of these are at once expelled from the cells as active enzymes, but some few require the co-operation of a specific activating agent before they can be converted into effective ferments. Trypsinogen, which is an excellent illustration of this class, requires the intervention of enterokinase, itself an enzyme, and hence called the enzyme of enzymes, or mother of ferments, by Pavlov.

Under special conditions many enzymes are capable of reversing their usual activity. Thus, instead of the substrate being converted into its usual end-product, this latter may become the substrate, and produce the former as its end-product—a condition termed reversible zymolysis.

It has not yet been demonstrated that the digestive ferments are capable of converting sugar into carbonic acid and alcohol, but the saccharolytic enzymes are quite capable of effecting this result. These are of two kinds, the former, sucrase or invertase, isolated by Berthelot, and capable of converting cane sugar into glucose; the latter, alcoholase, identical with the zymase obtained from yeast by Buchner, which splits the glucose into alcohol and carbonic acid. Besides which, Professor W. E. Dixon, of Cambridge, has shown that the bacillus coli can produce from 9 to 17 per cent. of alcohol when allowed to grow in sugar, and it is fair to suppose that as this action must take place in the colon, the alcohol so produced must pour into the system.

Hence, without the effect of living yeast cells, we are all alike subject to the results of the activities of quite similar ferments in the body, and, in fact, the action of the digestive and alcoholic ferments is practically identical. The minute quantity of alcohol contained in ordinary bread may therefore be safely ignored when we reflect on the probable amount that may be manufactured in the alimentary canal quite outside of our own control.

But if further evidence were necessary of the innocuous nature of yeast, it is to be found in the series of experiments conducted upon rats by Professor Leonard Hill in connection

with the controversy on the respective nutritive values of white and standard bread. The yeast employed in the manufacture of standard bread manifestly exerted no deleterious action on the rats, which flourished equally exuberantly under the nourishing influence of standard bread or standard flour. The fact that growth was stimulated to a like extent both by the flour and the bread is a sufficient indication that not only was the yeast harmless, but that its influence was a negligible quantity. It is perhaps rather unfortunate that this should be the case, as yeast is a substance rich in the organic compounds of phosphorus to such an extent that, as has already been mentioned, it can prevent the development of polyneuritis in animals fed upon rice, barley, and wheat flour in which the outer layer of the grain has been removed in milling, and where the disease is present its timely administration can cure it.

On the other hand, the effort to obviate any waste in the preparation of bread is entirely praiseworthy, although one may safely conjecture that when all precautions have been taken a certain percentage of waste is likely to arise. In yeast-raised bread, that which is associated with the conversion of a small proportion of the sugar is quite unavoidable, and to this extent the yeast-free bread is so much the more nutritious. On account of its close texture, it also compels much more careful mastication, although it is hardly likely to call forth such a large quantity of "appetite juice," until one has become accustomed to its use. Its devotees, however, appear to appreciate both its nutritive qualities and its flavour, and declare that "by taking unfermented food and by abstaining from the opposite, their sense of smell becomes regenerated, and the odour of putrescence inseparable from yeast is recognised as the odour of disease, and they can no longer endure to be in its presence." This statement is clearly the outburst of a zealot, because outside of a bakery it is quite impossible to detect the odour of yeast in association with well baked bread. The impossibility of swallowing the so-called "starvation compounds" of the ordinary baker is purely a psychological effect, and as such explicable on other grounds than those which appeal to the senses.

We are bound to commend these propagandists, however,

for their effort to produce a pure bread, made from washed wholemeal, finely ground, devoid of salt or other chemicals, and would recommend the ordinary baker to emulate them in such a desirable attainment. This would clearly lead to the more careful mastication and insalivation of bread, and by bringing the other items of food into harmony would unquestionably tend to inculcate the principle of moderation.

CHAPTER XIV

FORCED FEEDING IN THEORY AND PRACTICE

FASTING emphasises the principle of rest for the organs of digestion. As a system of therapy, it professes to set free the energy usually expended in digesting food for vital purposes, and to diminish the friction in the machinery of the organism by throwing off the waste matter accumulated by indulging in excess of nutriment. Its advocates assert that it is efficacious in restoring health without the necessity for having recourse to rest.

Forced feeding is the antithesis of this, claiming by an excess of nutriment and enforced rest to restore lost vitality, and in particular to give abundance of energy to those who have been too prodigal in its expenditure. The results of both methods of treatment are thus stated to be identical, but in every other respect the systems are hopelessly at variance.

Although it may be at once frankly conceded that the medical profession has practically no experience of the therapeutic value of prolonged fasting in disease, no array of scientific facts could so seriously menace its claims as the excellent results of treatment on the Weir-Mitchell plan. Employed in suitable cases, the latter can be credited with some of the most brilliant cures in the whole realm of therapy, although, strange to say, in one respect there is a great similarity between it and fasting.

Just as in the latter system the peccant material removed under its influence is stated to be an excess of nutriment, a condition quite unclassified and unrecognised by pathological anatomy, so in those cases in which the beneficent effects of hyperalimentation are most to be noted, viz., those of neuras-

thenia, pathologists have been unable to agree upon any alteration of the tissues to account for the disease.

In most cases, of course, there is a loss of fat and a considerable alteration in the quality of blood, but these are rather effects than causes. Whatever be the pathological anatomy of the condition, the real factor of importance is the daily expenditure of a greater amount of nerve force than can be manufactured to keep up the necessary supplies, and this in time so alters the whole nutrition of the nervous system that an efficient amount of sleep cannot be obtained to repair the daily waste. This in turn interferes with the digestive functions, impairs the quality of the blood, and the nerves of nutrition are still further exhausted, so that ere long a vicious circle is established which is most difficult to break. The only method whereby this may be accomplished is to improve the reparative processes of the body by restoring the sleep and digestive power, and reducing the expenditure of nervous energy to the lowest point possible; and the best means of effecting this is by the method now so well known as the "rest cure."

Application in Neurasthenia.—It would almost appear as if a modified form of fasting, or at any rate its equivalent of chronic under-nutrition, were associated with the etiology of neurasthenia, and it is clearly a paradox that what is represented as curing so many forms of disease should, in some sort, be responsible for the production of a diseased condition closely allied to the alleged "cured" condition at the end of a prolonged fast. It is difficult in such circumstances to eliminate the mental influences in either case, so potent for good in fasting, so potent for evil in the production of neurasthenia.

Whilst the loss of fat is not in itself a pathological incident of much importance, its rapid replacement is a factor of great moment in nervous exhaustion. It is usually the first indication that the processes of repair are being restored, and probably it is some such conception as this which obsesses the average man with such a wholesome dread of losing his adipose tissue. Even when a man is frankly obese, and announces his desire to be relieved of some of his superfluous flesh, the reduction of a few pounds frequently makes him

pause, as much from prejudice as from the remarks of his friends that he is getting thinner. His imagination is quickly overwhelmed with visions of the ravages of consumption, and he already considers himself the victim of this or some other disease connected with malnutrition. He has learned to associate loss of weight with loss of strength, and is unable to differentiate between a loss of what is simply an incubus and one which involves an encroachment upon his vital energies.

When the organs of assimilation are capable of renewing the supply—a supply which is doubtless being constantly consumed, and hence needs constant renewal—a mere loss of fat is a matter which we can afford to ignore. But when there is a persistent drain upon the subcutaneous layer of fat, we are in the presence of what may constitute a very real danger. It is then our duty to make an investigation into its causation, whether due to excessive loss or failure to furnish fresh supplies, so that we may be in a position to prevent any further encroachments on what is really a reserve of stored-up energy. We know from experience that when the daily supplies of fat cease to be replenished, the position is a grave one, as it is really only a question of time for the life stream itself to be attacked, and for some form of anæmia to supervene. Loss or gain of weight appears to synchronise with loss or gain of hæmoglobin in the blood, and this hypothesis is by no means disproved by the existence of a class of fat anæmic people, usually women.

Full-blooded or plethoric people are generally stout, and, as a rule, thin-blooded people are thin. The occasional obesity of anæmic people has been attributed to lessened tissue combustion, and that again to a supposed diminution of the number of red blood corpuscles, but in all probability it is accounted for by some constitutional peculiarity in those in whom the percentage of hæmoglobin is reduced. It is a well-known fact that bleeding used to be resorted to for the purpose of increasing the deposit of fat, as, after bleeding, a good deal less oxygen is absorbed from the pulmonary surface; but this is, of course, explicable by the reduced amount of hæmoglobin, consequent upon the diminution in the number of the red blood corpuscles.

Fat and Nutrition.—Some fats are said to be wholesome

and others are not, and the statement becomes intelligible when we study the process of fat digestion. This occurs, in its initial stage, probably in the duodenum, where the fat is split into fatty acids and glycerine, which, upon being absorbed by the cells and small intestine, are immediately reconverted into fat and reach the blood through the lymphatics. It is not then built up into the cell substance like protein, but deposited in the areolar tissue, and hence is very similar in appearance to the fat used in the food. Experience has shown that the fat of hay-fed horses is soon dissipated, and in like manner the adipose tissue which is quickly manufactured during a course of cod-liver oil rapidly melts away when its administration is stopped. Mutton fat, on the other hand, is firm and solid, and when used as a dietetic agency by those having a phthisical tendency, is the progenitor of a much firmer and more lasting adipose tissue.

It may be mere fancy to imagine that the nature of the subcutaneous fat has any significance of value in such patients, although it has always appeared to me to have, but in any case simple accumulation of fat globules in the tissues is a factor of very little importance in tuberculosis. Fat is, at the best, only an indication that the nutritional functions are in working order, and its rapid evanescence with little ultimate benefit to the tissues gives us reasonable ground for inferring that different forms of fat have different values in the economy. Breeders of stock certainly believe this, and aim at the production of firm fat, which will not vanish in the form of liquid grease on cooking, and any one who has experienced the inferior staying power of American bacon as compared with our home-grown product will have no difficulty in assenting to this proposition.

By proper feeding Weir Mitchell declares that during a rest cure fat appears first on the face and neck, then on the back and flanks, thereafter on the abdomen, and last of all on the limbs—the legs particularly being very tardy in acquiring a deposit. In everyday life one is accustomed to note in the obese that fat first accumulates on the abdominal wall, but, doubtless, this is accounted for by the fact that the muscles of this region are so little used in proportion to those in other parts of the body, and the active and continued use of any

set of muscles directly reduces any adipose matter in their immediate neighbourhood. The inference is that fat is in a continual state of removal, being deposited from the blood and again absorbed by the muscles in their daily activities.

Normal Amount of Adipose Tissue.—All healthy people should possess a certain quantity of fat, but the proportion must necessarily vary, the average being from 18 to 22 per cent. of the body-weight in an adult man, and from 25 to 28 per cent. of the body-weight in an adult woman. It is a comparatively easy matter to effect the dissipation of fat in anybody, provided the proper conditions are observed, but it is a much more difficult matter to effect an increase in the adipose tissue and so produce a gain of weight. But if those suffering from the consequences of chronic exhaustion are to derive any real lasting benefit, they must be coaxed or compelled to make a substantial increase in their weight. Many people are perfectly healthy with a minimum of subcutaneous fat, but neurasthenics, especially when the seat of their trouble is in the alimentary canal, do not make progress nor maintain their improvement unless a certain amount of reserve adipose tissue be accumulated.

Fat can be deposited in the tissues from the consumption of any of the three chief classes of food-stuffs, and there is little doubt that the fatty globules deposited in the body are capable of contributing in some way, directly or indirectly, to the formation of muscular tissue. It may be that these act only in the capacity of protein spacers, but in any case in this lies our chief hope in the regeneration of such patients, for the renewal and strengthening of their muscular tissues is an absolute necessity. The chief protein tissues are blood and muscle, and the amounts of blood and protoplasm as represented in the composition of muscle have a definite relation to each other, in health the latter depending directly on the former. It is very difficult to fix a standard of muscular bulk or fitness, but there can be no question that an individual only attains to the best health when his muscles are developed to their full physiological limit.

Our chief aim, therefore, in all cases of nervous exhaustion, is so to augment the supply of nutriment and diminish the expenditure of energy that a reconstruction of the tissues—particu-

larly those of the involuntary muscles, like the alimentary canal, heart, and minute arterioles throughout the body—may be effected. The important element in such a case is of course forced feeding, and the quantity of food required to accomplish our object will vary with the weight of the individual. It is therefore requisite in the first place to estimate the maintenance diet, and the amount ingested above this quantity is surplus of food, which von Noorden has calculated will increase the weight from 600 to 1,000 grams weekly for a daily addition of 500 to 800 calories.

Forced Feeding Defined.—Forced feeding, therefore, may be defined as any caloric excess over the ordinary nutritive requirements of the body, and is always associated with a retention of nitrogen, not necessarily in the form of muscular tissue. Every gram of retained nitrogen is equal to 6.25 grams of albumin, which quantity is contained in 29.4 grams of muscle tissue. But it is known that the retained nitrogen is not incorporated with the active protoplasm of the body, because it does not contribute to the consumption of oxygen, nor on the other hand can it be found in blood. For this reason von Noorden has promulgated the doctrine that it is stored as a reserve stock of albumin in the cells, just as fat and glycogen are, and it may be that it has a different construction from the ordinary protoplasm of the cells. As a point of practical importance, it is worth noting that casein supplies proportionately more of this retained nitrogen than the protein of eggs, meat, vegetables or fruits, and as much as from 2 to 6 grams may be accumulated daily, although after cessation of the overfeeding the unutilised excess is rapidly dissipated as urea.

There is not a single scrap of evidence in support of the conception that "flesh" or muscular tissue is increased by overfeeding, but it is certain that a reserve stock of protein, fat, and glycogen must first be accumulated in the body before any attempt can be made to promote the actual growth of muscle. This can only be effected by active use of the muscles, and Zuntz has shown that systematic exercise is accompanied by a loss of weight, chiefly due to the consumption of fat, but the muscles are increased in size, and as a concomitant there is a greater increase in the consumption of energy.

Flesh Formation.—Actual tissue development or flesh for-

mation is known to take place in the body during growth, during pregnancy and lactation, during convalescence from such disease or illness as has occasioned loss of flesh, and, as a result of everyday experience, in those who are performing more muscular work than usual. Overfeeding *per se* is unable to accomplish this. Actual exercise of the muscles is necessary to stimulate their growth, and this may even occur when the protein ingested is less than the nutritive requirements of the body would warrant. But a certain excess of nutriment must be at the disposal of the body to enable it to develop in the most efficient manner, both as to its muscles and for the accumulation of adipose tissue.

Development or even efficient maintenance may be inhibited by various toxins as well as by a deficiency in the supply of reserve material, and many asthenic conditions may be caused simply by the removal of those toxins without supplying an excess of nutriment. It is a mere accident that the administration of iron should cure anæmia, and certainly the amelioration produced is not due to the addition of some missing factor in the diet, but because of the stimulation of the hæmatogenic properties of bone marrow, an event which may be equally well accomplished by arsenic. This plainly shows that anæmia is not due to a deficiency of iron in the food so much as to an inability of the tissues for some reason to utilise it.

Tissue-building is really a potentiality inherent in the cells. It may be diminished by lessening the supplies of nutriment, but it is doubtful whether it can really be increased by over-nutrition any more than by providing a maintenance diet.

It is a very different matter with the adipose tissue, which can be increased within limits in any degree that is considered advisable. It is only a question of augmenting the quantity of food beyond the nutritive requirements of the body, and after certain deductions have been made, the surplus becomes fat. Eight per cent. of the energy of the surplus food is utilised in the processes of digestion and absorption, 4 per cent. remains unabsorbed, 10 per cent. is stored in the cells as reserve protein, and an unascertainable but small quantity becomes glycogen. All the rest of the surplus food becomes fat, and should it amount to 930 calories, would mean a deposit of 100 grams of fat.

The Best Fattening Agent.—So long as the food is suited to the individual capacity and idiosyncrasy it is really immaterial for fattening purposes whether we depend upon protein, carbohydrates, or fats. Proteins are certainly the least useful, for besides 12-15 per cent.—much beyond the average—which is lost in their digestion and absorption, some of their energy is dissipated in increasing the oxidation processes, an operation designated by Rubner as their dynamic action. The amount capable of being added to the diet is also limited because of their tendency to diminish the appetite, and no advantage is obtained by employing the various concentrated proteins, although the soluble varieties are more helpful than the insoluble.

Carbohydrates are more useful, but on account of difficulty in their assimilation they cannot be increased indefinitely. Altogether 25 per cent. of their value is lost, including 10 per cent. in their digestion and absorption, and a considerable percentage of heat which is wasted during their transformation into fat. When combined in an agreeable manner with fats, *e.g.*, porridge, or a breakfast cereal and cream, or in the form of extract of malt, they are much more easily utilised. In any case it must always be remembered that carbohydrates are protein—and therefore tissue—saving. Employed as fattening agents in animals, they frequently produce fatty degeneration of the heart, and this is an additional reason for not placing too much reliance upon them for augmenting the deposit of fat.

Of all food-stuffs, however, fat is the one best fitted for increasing the store of adipose tissue, not only on account of its high calorific value, but because it sustains practically no loss of energy in its passage through the alimentary canal, not more than $2\frac{1}{2}$ per cent. being dissipated in the process of digestion and absorption. It is a truism that people who are fond of fat never require a rest cure, and in this connection it is worth while pointing out that Voit's standard of 56 grams is decidedly too low, and that 100 grams should be the minimum daily allowance of fat in any dietary. This quantity may easily be trebled during forced feeding if personal idiosyncrasy be taken into consideration, but in any case at least 200 grams should be insisted upon. It is wise not to give it in an unusual form, but to adhere to the kind commonly included in the diet

list, such as butter, milk, and cream, because these may be continued as an increased ration long after the formal cure has ceased.

The fattening properties of alcohol being indirect, and in the nature of a diminution of the metabolic powers, and the general effect being toxic, it is injurious to rely upon this agent in ordinary circumstances.

Recognising these facts, it is usually a very simple procedure to enable a patient suffering from any form of chronic under-nutrition to increase his weight and strength, and although in severe cases of nervous exhaustion it is, perhaps, essential still to prescribe a complete rest-cure of the Weir Mitchell type, with isolation, perfect rest in bed, and passive exercise in some form, it is rarely necessary to recommend such an expensive form of treatment, excellent results being obtained by a modification of the process. This is specially the case in those who have lost weight, and become anæmic from constant dyspepsia, due in a great measure to a certain degree of gastropnoia, and whose digestion is effective or otherwise according to the efficiency of the motor power of their stomach. This, again, is a fluctuating quantity, dependent on the amount of nervous energy dissipated in the day's work. In such patients a considerable proportion of the food undergoes a process of degradation from its long retention in the stomach, and is quite incapable of advantageously nourishing the tissues. Hence when they can take a sufficiency of nutriment they are unable to obtain its full caloric value, although very little research has been made into the nature of the end-products of the food-stuffs in such cases. It is known, however, that in addition to the damage to the tissues by the nutritive loss, there is formation of toxins, the absorption of which is productive of the profound depression so constantly observed in dyspeptics.

THE MODIFIED REST CURE

In these cases the most appropriate form of treatment consists in a modified rest cure of, at the longest, three months' duration. The first three weeks of this time should be spent almost entirely in bed, the patient only rising to

defæcate, urinate, and perform his necessary ablutions, and after the first week to indulge in a few Swedish movements. In addition, twice a week a very hot bath should be administered. During the fourth week one hour per day should be spent in gentle outdoor exercise, and this should be increased to two and three hours in the fifth and sixth weeks respectively. The next six weeks should be spent in a country or seaside holiday, during which the patient should gratify his desire for exercise well within the limits of fatigue, and should particularly reserve one hour or more after each meal in which he should resume the recumbent posture, if possible in the open air.

The only treatment prescribed during all this period is the forced feeding, which I shall proceed to detail, and the application of an india-rubber bottle half full of very hot water right over the region of the stomach every two hours. It is important that this should not be too large—12 inches by 8 inches is a useful size. It should only be half full of very hot water, should be covered with flannel, and it should rest to a greater extent on the lower ribs than on the yielding tissues over the gastric region. The object of this is, of course, to prevent restriction of the gastric movements by direct pressure, and on the other hand to stimulate the contraction of the gastric musculature by the application of heat all over its immediate neighbourhood. Towards the end of the treatment the cutaneous area of the epigastric region assumes the appearance of bacon rind—if, indeed, the cuticle does not peel off like the skin of a new potato.

The diet consists of two small meals, two large meals, and at least three glasses of hot milk at convenient intervals between meals. At 7.30 a.m. breakfast should be served in the shape of the yolks of two eggs poached on toast, bread and butter with marmalade or jam, and one or two tumblerfuls of hot milk. At 10.15 a.m. one glass of hot milk. At 1 p.m. dinner, a typical example of which would be a little soup, three-quarters of a pound of any kind of flesh food (roasted), with potatoes and green vegetables, pudding, stewed fruit and cream, and 5 ounces of mineral water. At 4.14 p.m. bread, butter, jam, and one pint of hot milk. At 7 p.m. a supper like the dinner, and at 10 p.m. one glass of hot milk.

At first the unfortunate patient, who has not eaten a "square" meal for many years, perhaps, feels quite uncomfortable from the hyperalimentation, especially when sitting up in bed to eat; but the moment he lies down and obtains the soothing hot-water bottle his discomfort is exchanged for the glorious sensation of satiety and heavenly rest. The hot-water bottle should be applied both night and day, and for many months after the treatment proper is completed should be continued after meals and at bedtime. I am in complete accord with Dr. Hutchison when he says that the whole life of a gastrotropic patient must partake of the character of a more or less modified "rest-cure."

On such a modified system I have frequently known a patient put on 1 pound per day of much-needed weight, and although he lost a good deal of the excess of fat on resuming work, he retained a sufficient quantity to prevent the expenditure of his energy from exceeding the income. Nor is it necessary to initiate the treatment by a preliminary fast for two or three days, then passing on to a graduated system of dieting, as some do. Cases of the type I have mentioned do well on the full diet from the very first meal. No particular form of food is indicated. All that is necessary is to ensure a sufficient supply of good wholesome nutritive material, and I have obtained as good results on a fleshless system of diet as on a mixed diet, although the latter is always to be preferred.

Although my experience in this method is confined to functional cases of stomach ailments, I am quite certain that it would be suitable for many other forms of malnutrition, such as muco-membranous colitis, and neurotic cases of many kinds.

Its Rationale.—The beneficent effects of this treatment are due in the first instance to the excessive quantities of food. Most cases consume with ease about 7 pounds of food per day, if we include the milk, and this is just a little less than double the total quantity of the day's rations of an average healthy man. The heat and energy value will not exceed 4,000 calories, which is again just twice what is required by a patient at absolute rest. The fact that practically no benefit is obtained unless the weight is materially increased confirms

the view that hyperalimentation is the most important factor therein. The weight, however, must not only be increased: the increase must be maintained, and as we know that deposited fat is constantly being utilised by the tissues, this means that there is a daily renewal, for which purpose digestion and metabolism must be preserved at a higher standard than existed before the cure was undertaken. The internal work of the body is therefore much augmented, but the organs are able to work under better conditions, because, as there is no external work, and therefore less waste matter and fewer toxins to interfere with their functioning, all their energies are devoted to improving their own nutrition. The absence of all signs of indigestion and the regular daily action of the bowels—which is always a surprise to those who believe that the recumbent posture encourages constipation—most unquestionably demonstrate the improved condition of the stomach and bowels, whilst the cessation of the wearing, aching pains in the limbs proclaims in no uncertain manner that the toxins of fatigue have been effectively excreted. These indubitable benefits have been accomplished despite the enormous excess of nutriment in the tissues, disproving the statement that it is a factor in the production of disease. The large supplies of fluid in the shape of milk increase the urinary and cutaneous excretions, and doubtless have their share in the advantages derived.

FORCED FEEDING AND MODERATION

At first sight the system of forced feeding may be considered a violation of the principle of moderation, which—as must now be apparent to all my readers—is the fundamental dietetic doctrine inculcated in this book. But a closer inspection will reveal rather an anomalous state of affairs, which will bear careful examination. A little reflection will prove that the nutritive demands of the type of patient I have described as being most benefited by a modified rest cure are generally in excess of the nutritive requirements of a healthy man of the same build and age. Whether from an hereditarily unstable nervous system or a wrong method of education or an unsuitable occupation, patients of a nervous temperament are characterised from their cradle to the grave by the performance of

purposeless actions. This perpetual fidgetiness devours energy that they can ill spare from the digestive processes, whilst in addition the lack of a coating of subcutaneous fat greatly augments the loss of heat from the body, and the conversion of much of the food into non-nutrient—not to say toxic—end-products makes an expensive inroad into the daily ration. Hence, instead of the 2,400 or 2,500 calories which would be ample for the nutritive requirements of a normal reposeful man of the same age and build, 2,700 to 2,800 would hardly suffice them, and as their digestive system would certainly not cope with such an amount, they are daily compelled to draw upon their own tissues for much-needed sustenance. The physical bankruptcy which ensues can only be evaded successfully by an immediate increase of capital, and when this has been obtained it must cease to be dissipated in the prodigal manner of the past and diverted into healthy channels of renewed activity. The store of fat, which should be maintained as far as possible for many months after the completion of the cure, is thus by careful graduated exercises utilised for the building up of muscular and nervous tissue, and when the restlessness of the past is replaced by a reposeful and energetic life of action, every calorie of the nutriment is employed to the best purpose.

The principle of moderation can then with advantage be introduced into the life and take the place of the spendthrift policy of the past. There being no longer any inordinate drain upon the energy because of the cessation or diminution of purposeless movements, and no increased demand for heat-producing food to supplement the caloric necessities of the body because of the deposit of adipose tissue, the amount of nutritive material called for is notably less than before, and is well within the capacity of the digestive organs to supply. Most important of all, the digestion being now practically normal, and its end-products well suited for the purpose for which they were originally intended, every grain of the food contributes its share in the production of heat and energy, or takes its place as one of the stones for building-up or repairing the tissues. The production of toxic products is therefore reduced to a minimum, and the irritation of the nervous structures and interference with the metabolism, to say

nothing of the loss of energy in excretion, no longer exist. In other words, the former wasteful extravagance in the working of the body is replaced by economic and harmonious operations which tend to produce a more equable balance between the waste and repair. Hence, despite the increased weight, a smaller amount of food is actually required to satisfy the nutritive requirements of the body than had hitherto been necessary.

CHAPTER XV

FASTING IN THEORY AND PRACTICE

FASTING is the apotheosis of the principle of moderation. Except in a modified form it can hardly be said as yet to have attained to the dignity of a method of dietotherapy, although in recent years it has been somewhat persistently advocated by certain irregular practitioners as a panacea for all kinds of disease; and as in their estimation everybody is diseased, occasional total abstinence is accordingly sanctioned by them. Perhaps because the very simplicity of the treatment commends itself to the parsimonious, or more likely because of the strength of the mimetic faculty in human nature, sporadic outbursts of the fasting fad occur at regular intervals, during which the most unwarrantable claims are made for its efficacy and the most unmitigated nonsense is uttered by its devotees.

THE LAYMAN'S VIEWS ON FASTING

More or less lengthy treatises have been written by quite irresponsible individuals claiming to have wrought most marvellous cures by fasting, and as misconceptions on the matter which pass for scientific truth have crept into the daily Press and all sorts of periodicals, it can hardly be considered untimely to counteract the undoubted evil influence of such publications by an accurate description of the actual changes which take place in the body during fasting. Meanwhile, a brief glance at the layman's point of view and the errors into which he has fallen may not be out of place, and may indeed have a practical value.

The fundamental doctrine on which the layman's therapy is based consists in the dictum that disease is an encumbrance of the system with effete mal-assimilated foreign materials due to excess of nutriment, and is indeed simply an attempt of the body to rid itself of accumulated impurities. He labours to prove that disease cannot possibly be an entity, ignorant of the fact that medical men regard such an idea as a concept of mediæval pathology. He advances no proof, however, for his own crude etiological teaching that the morbid material, which is at the root of all disease, is simply an excess, or due to an excess, of food, and that, as disease is only a manifestation of Nature's efforts to extrude this accumulation from the body, her efforts should not be frustrated, but seconded. Were this paradoxical doctrine applied in the manner suggested, it is to be feared that homicide would soon form another of the many charges to be laid at the door of the medical profession.

We quite agree that were we to eat just enough and no more than would suffice to balance the bodily waste and repair, what is called morbid accumulations would not be likely to arise, but we are not inclined to interpret this statement with the same strictness as he does. The body is not a test-tube in which the double decomposition of nutrient materials occurs in the precise and quantitative definite manner of a chemical reaction. The functioning of the various organs is conducted on much more spacious principles, and they are capable of dealing with widely varying quantities of nutriment, and with much more waste matter than is suggested by the shortsighted statement to which we have just referred. The excision of a kidney, or an eye, or even a stomach, is followed by such compensating efforts on the part of the body, that in a comparatively short space of time it is hardly missed. We cannot therefore agree with him when he says or implies that in the absence of strictly quantitative dieting disease must arise. Nor can we subscribe to his claims that food taken in excess of the bodily requirements for the time will in no way help the body, but feed the disease, whereas by fasting we may cure the disease by withdrawing the nutriment on which it is dependent. Sufferers from neurasthenia are from every point of view diseased, and super-

alimentation should therefore intensify their disease with all its distress, but the delighted subject of a successful "rest cure" will not readily acquiesce in such a misstatement.

Scientific Researches on Fasting.—By far the best way of demonstrating the fallacy of the dictum that a prolonged fast only rids the body of superfluous excrementitious material, leaving the healthy tissues absolutely intact, is to take a comprehensive survey of the facts elicited by scientists in their careful study of the problem. For many years research on these lines was confined to German, French, and Italian investigators, but in more recent times the attention of British and American workers has been directed to the subject with valuable results. The main conclusions on the subject have been drawn from the accurate observations made upon professional starving men or "hungerkünstlers," chief among whom are Cetti, Breithaupt, and Succi.

At the very outset, however, it is necessary to define with some accuracy precisely what is meant by fasting. Briefly it may be considered as the deprivation of all or any of the elements essential to nutrition. It may therefore be (1) *Complete*, which means the absolute deprivation of food and water after a period of good nutrition, the only addition to the bodily resources being the 500 grams or thereby of oxygen inhaled in the daily respiration. In this form there is never a gain of weight. (2) *Incomplete*, which is usually held to cover a similar operation with the addition of a certain allowance of water. In this form there may or may not be a gain of weight, according to the amount of water consumed. For instance, in the case of Dr. Tanner, an American physician, who fasted for forty days, there was, after sixteen days of complete fasting and consistent loss of weight, a gain of $4\frac{1}{2}$ pounds brought about by drinking a considerable quantity of water.

The designation incomplete fasting may also be held to cover those cases where only one or two of the alimentary principles are withheld. These are, however, generally incapable of affording information of real value on fasting, although they may be of deep scientific interest otherwise; *e.g.*, Straub fed a dog on dry meat powder mixed with fat, which necessitated a withdrawal of water from the tissues to dissolve

the urea formed. The muscles lost 20 per cent. of their water and the protein metabolism was decidedly stimulated, but owing to the lack of fluid the digestive secretions decreased in amount, and all the food was vomited. In this way the experiment was reduced to one of complete fasting. Death from fasting occurs much more quickly where water is withheld, and in prolonged experiments it is usually administered in small quantities.

Von Noorden also classifies fasting experiments under two heads—(1) *Acute Starvation*, which includes both of the subdivisions already mentioned, and (2) *Chronic Starvation*, or malnutrition the result of weeks or months of insufficient nutrition. It is mostly in cases of this kind that the layman advises fasting as a therapeutic agency, and bases his deduction on facts drawn from their observation.

Metabolism during Fasting.—Rubner has formulated the law that the expenditure of energy during starvation is diminished in the same proportion as the weight of the body, and it is notable that during the first few days of acute starvation the general metabolism undergoes little or no diminution. The body appears to use up the same amount of material, and makes inroads into its own tissues in lieu of other food supply. In a case under the observation of Voit and Pettenkofer, 2,362 calories were expended whilst being fed, and 2,320 calories during starvation. In other cases similar results were obtained, any increase, apparent or real, being due to the work of digestion and the necessary chemical changes in the food, which would not account for more than an average of 10 per cent. From 30 to 32 calories of energy per kilo of the body-weight are expended by fasting persons daily. During complete repose in this state it is possible to determine accurately the minimal metabolism for the individual.

For purposes of reference, it may be useful at this point to set forth in detail the maintenance diet for a man of 70 kilograms under varying conditions. Von Noorden gives the following figures:—

About 30 calories per kilog. : when resting in bed					= 2,100 cal.
32-35	"	"	"	confined to the house	= 2,240-2,450
35-40	"	"	"	taking light exercise	= 2,450-2,800
40-45	"	"	"	moderate physical exercise	= 2,800-3,150
45-60	"	"	"	engaged in severe labour	= 3,150-4,200

When these figures are decreased by less than 20 per cent., then the individual is in a condition of mild undernutrition, and when they are reduced by more than 60 per cent. a state of severe undernutrition exists.

During the first few days of deprivation from all food there is still a supply of glycogen in the muscles and the liver, but when this is expended the fasting man is compelled to live on protein and fat, and Tigerstedt has shown that on the fifth day 14·5 per cent. of the energy was derived from protein and 85·5 per cent. from fat. For this reason the respiratory quotient, *i.e.*, the proportion of the oxygen intake to the oxygen output in the shape of carbon dioxide, falls from 1·0, which indicates the combustion of carbohydrates, to a lower figure, ·707 indicating fat, and ·809 protein. The more rapidly the value falls to this amount the smaller has been the supply of glycogen in the tissues. When it falls below the lowest figure it indicates that the carbon and oxygen, instead of being exhaled entirely by the lungs in the form of carbon dioxide, are excreted by the kidneys as acetone, diacetic, and β oxy-butyric acids. Lehmann and Zuntz have also succeeded in demonstrating that in perfect repose the decomposition of protein permits of the formation of a little glycogen in the liver and muscles. Hence the respiratory quotient is increased during muscular work.

As during fasting all the excretions continue in some degree, the body must depend for its pabulum on what it already contains, apart from any water which is consumed. The decomposition of protein or, as it is called, the katabolism of the protein during fasting indicates the extent to which the tissues have been used for providing energy for the body. Quite 90 per cent. of the nitrogen of the muscles and the glands is in the form of protein, the other 10 per cent. being extractives, and 99 per cent. of the total nitrogen of the blood is in the form of protein. It may therefore be concluded that the nitrogenous metabolism is practically identical with the actual protein metabolism, as the ratio of protein to extractives does not alter during fasting. Therefore, 90 per cent. of the total nitrogen excreted is derived from the breakdown of protein in the blood and tissues. This amount can easily be estimated from the excretion of nitrogen in the urine by multiplying the

grams of nitrogen excreted by 6.25—because there is in the average 1 gram of nitrogen in 6.25 grams of protein—after adding to it .2 for the daily nitrogen-content of the fæces. In every case the excretion of protein nitrogen means that the tissues of the body are being broken down, whereas when protein nitrogen is retained the bodily tissues are being supplemented. The amount of flesh disintegrated is calculated by multiplying the nitrogen excreted by 29.4, *i.e.*, 4.7×6.25 , as flesh contains 3.4 per cent. nitrogen, while muscle protein contains 16 per cent. nitrogen.

The amount of nitrogen excreted during the first three or four days of fasting is always greater than at any subsequent period, because it is dependent upon the protein intake and the breakdown during the days preceding the fast. This supplies a variable quantity of what is termed labile protein—which corresponds to the “circulating proteid” of Voit, and the excretion of nitrogen will be greater or lesser according to this amount. Voit declares that 8 per cent. of the stable protein or “tissue proteid” and 70 per cent. of the labile protein are decomposed during fasting, and if this be so the latter is all consumed during the first three days. In any case, it is certain that at the end of the third day only 3 per cent. of labile protein can be obtained from the blood, and hence from the fourth or fifth day onwards only stable or tissue protein can possibly be available.

In carnivorous animals like the dog, the fall of the protein katabolism is particularly well marked, although in man there may be an increase on the third or fourth day, owing to the glycogen in the tissues being all utilised. Thus in Breithaupt 10 grams of nitrogen were excreted in the urine on the first day, 9.9 grams on the second day, 13.3 grams on the third day, 12.8 grams on the fourth day, and only on the sixth day was the figure 9.9 grams again reached, demonstrating the obvious fact that he had been extremely well fed. before his fast. After the first two or three days an average loss of 10–13 grams of nitrogen takes place for the next week or ten days, although it is relatively greater in the thin than in the stout, and in the small than in the large men. Fasting women also excrete from 20 to 30 per cent. less nitrogen than fasting men. Cetti, who weighed 57 kilos, excreted daily during the

first ten days 10–11 grams nitrogen, equal to 60–70 grams of protein. A young man weighing 60 kilos lost during the same time 11 grams nitrogen daily, equal to 70 grams of protein. In neither case was there much adipose tissue. In fatty subjects the nitrogen excreted was found to be much less, *e.g.*, Succi, who weighed 63 kilos and lost 11 kilos during a thirty days' fast, on the tenth day excreted 6·7 grams nitrogen, 49 per cent. of the output on the first day; on the twentieth day excreted 4·3 grams of nitrogen, 32 per cent. of the output on the first day; on the thirtieth day excreted 3·2 grams nitrogen, 30 per cent. of the output on the first day.

Estimating the average for men of 70 kilos as 13·7 grams nitrogen, or a loss of 90 grams protein, equal to 1·2 grams per kilo of body-weight, this would only account for something less than 400 calories of energy per day. It is manifest that energy must be obtained from some other source than the protein, which is only able to supply 15 per cent. of the metabolic requirements of man during starvation. The remaining portion is satisfied by the stored-up fat, and the greater the quantity of this, the greater proportion of energy will it supply. When the fat stored up as adipose tissue has been almost totally expended—and the remnant resists oxidation in a marked degree—then greater inroads are made upon the tissue protein. Hence a premonition of approaching death is supplied by a rise in the excretion of nitrogen, although at the very close of life this amount again sinks. The addition of carbohydrates and fat alone to the diet will always reduce the excretion of nitrogen, thus displaying their protein-sparing qualities.

In herbivorous animals, at the beginning of a fast there is an active and decided increase of the nitrogen excreted in the urine, because, being compelled to use up their own tissues, they become, for the time being, carnivorous. In the case of Voit and Pettenkofer already mentioned, 1,999·5 calories were evolved from fat and only 320 from protein. The longer the fast is continued the smaller is the protein decomposition—the valuable protein being saved at the expense of the less valuable fat. During the progress of a fast the share of protein in the total metabolism amounts to from 7 to 17 per cent., calculated in calories. This is, of course, derived from the tissues, and

as the proportion is much less than the normal, it probably indicates that tissue protein is not so easily decomposed as food protein, of all food-stuffs the most freely disintegrated, although it is doubtless also a mark of the value placed by the body on its own tissue.

The protein consumed is derived chiefly from muscle, although the liver, the pancreas, and other glandular organs contribute a share, as they are diminished in size. Voit has shown, however, that this is not necessarily due to any structural alteration, because they are prone to regain their size rapidly when water is administered. When actual loss of tissue substance has been sustained sufficient to modify the structure of the organ, reconstruction is, even in favourable circumstances, a slow process.

The exhalation of carbon dioxide from the lungs is in direct proportion to the body-weight and to the work done, and in inverse proportion to the surrounding temperature. A man weighing 71 kilos excreted on the first day 201.3 grams carbon by the respiration and 5.8 grams carbon by the urine, equal to a consumption of 78 grams of protein and 215 grams of fat, or about 370 grams of flesh. During the first working day 75 grams of protein and 380 grams of fat, equal to nearly 478 grams of flesh, were lost. During the first day 760 grams oxygen were inspired and 889 grams carbon dioxide were exhaled, while during the work day 1,072 grams oxygen were inspired and 1,777 grams carbon dioxide were exhaled.

In another case weighing 70 kilos, on the second day 8 grams nitrogen and 3.7 grams carbon were found in the urine and 180.9 grams carbon were exhaled by the lungs, equal to 50 grams of protein (235 grams flesh) and 208 grams of fat. In these calculations it should be remembered that for every gram of nitrogen in muscle protein there are 3.28 grams of carbon, and that any excess of carbon in the excretions signifies fat destruction, fat containing 76.52 per cent. of carbon.

It should be noted that during fasting work has no influence in increasing protein metabolism, but enormously increases the combustion of fat. This, of course, has a direct effect on the excretion of carbon dioxide, which is reduced to about 20 grams per hour during sleep, as compared with

from 30 to 40 or more grams per hour, according to the severity of the occupation, during the daytime. Sitting up in bed or even a moderate degree of restlessness or nervous activity suffices to increase the metabolism, and therefore the output of carbon dioxide.

Loss of Weight in Fasting.—As the body is essentially composed of the alimentary principles, and as the total carbohydrate-content of the body in the shape of glycogen falls decidedly short of 400 grams, it is manifest that the moment this is utilised—and this is not a difficult matter—the organism must fall back on the protein and fat for its energy production. The combustion of these substances, with the excretion of their end-products in addition to the mineral salts and water, must necessarily be accompanied by a loss of weight. On the tenth day of his fast Cetti had lost 6·35 kilos, equal to 11·14 per cent. of his original weight, and on the thirtieth day Succi had lost 14·3 kilos, equal to 22·7 per cent. of his weight just before the fast began. Although adipose tissue is easily and rapidly burned up, the fat, in the form of lecithin—a definite component part of the protoplasm—resists decomposition to a large extent. The loss of weight for the first week is from 800 to 1,000 grams daily, equal to from 1 to $1\frac{1}{2}$ per cent. of the body-weight.

The disintegration of protein is more regular, although even in this case there is a differentiation between the various forms of protein, especially the nuclein of the cell resisting longer than the rest of the bioplasm. During the first few days the phosphorus-free albumins are decomposed, and thereafter the phosphorus-containing albumins are attacked. The loss of weight is at first more rapid than at a later date, and is never relatively great when small quantities of water are being consumed. In a short fast, indeed, the body-weight is wholly without significance, because as much as 100 grams of fat, equal to 930 calories, may be withdrawn and are capable of being replaced by an equal quantity of water. It is important to note that the loss of body-weight is greater when protein is being drawn upon for energy than when this is derived from fat, for 1 gram of body fat always produces 9·3 calories, whereas 1 gram of flesh only represents ·8 calorie by its combustion.

Estimation of the results of a fast by observation of the body-weight is, therefore, distinctly misleading and elusive. Any gain in weight during a fast can only be accounted for by the absorption of water, and it is therefore futile to suggest that death occurs when a definite proportion, say one-third or one-half, of the body-weight is lost. Rubner calculated that as much as 70 per cent. of the potential energy of the body tissues may be lost, this being divided somewhat as follows:— of the fatty tissues, 95 per cent. disappear; of the muscles, glands, and blood, from 40 to 60 per cent. may be dissipated; and of the bones about 15 per cent. is lost, while the nervous system only loses from 1 to 2 per cent. of its weight.

In no known fast of any duration has there ever been a gain of weight, and scientists all agree that the loss of weight is fairly uniform, although a little higher at the beginning than towards the close, as might be expected from the gradual decline of the functional activity of the organs. In cases where daily injections of water to a considerable extent are administered, on the mistaken conception that thereby the excretion of deposited morbid material will be hastened, a fairly large proportion may be absorbed, and this would account for an apparent diminution in the average loss of weight. It must be repeated with emphasis that in all cases the body lives on its own tissues, and so long as adipose tissue is present this is used in preference to the vital tissue of the body. In a case reported by Rubner the daily nitrogen output was 1·67 grams for the first three days, 1·46 grams from the fourth to the sixth day, and 3·21 grams from the sixth to the eighth day, while the fat burned on the second day was 10·3 grams, the same on the fourth day, and only 2·4 grams on the eighth.

On the average about 12 ounces (350 grams) of weight per day are lost during a prolonged fast of over thirty days' duration, and this is valuable tissue material extracted from the healthy tissues of the body. It is an absurd fallacy to suggest that it is a clearing away of excrementitious material. At the very outside muscle contains not more than 2 per cent. of waste products, so that the average man's body contains in all no more than 2 pounds of waste material. This weight may very easily be lost during the first twenty-four hours of a

fast, and any further loss of weight during its progress can only be ascribed to the consumption of the bodily tissues themselves. In other words, the subject of the experiment is for the time being a cannibal, and this explains many phenomena that would otherwise be unaccountable.

Lusk quotes Kumagawa's results, showing the percentage weights of the different organs in the fat-free organism of a dog before and after a twenty-four-day fast, and also the percentage loss of the fat-free organ in starvation:—

LOSS IN WEIGHT OF DIFFERENT ORGANS DURING STARVATION.

Organs.	Fat-free animal contains in percentage of weight		Fresh fat-free organ loses in percentage weight during a 24 days' fast.
	Well-nourished.	Starvation.	
Skeleton	14·78	21·50	5
Skin	10·30	11·29	28
Muscles	53·77	48·39	42
Brain and Cord ...	0·94	1·11	22
Eye	0·11	0·16	3
Heart	0·54	0·69	16
Blood	7·14	5·69	48
Spleen	0·39	0·26	57
Liver	3·98	3·05	50
Pancreas	0·33	0·19	62
Kidney	0·66	0·45	55
Genitals	0·30	0·23	49
Stomach and Intestine	5·81	6·02	32
Lungs	0·89	0·97	29

THE QUALITY OF THE BLOOD DURING A FAST

If one were to neglect John Hunter's dictum, "Don't think, but try," he would be led into all sorts of misconceptions regarding the changes in the quality of the blood. As might be expected, there is a slight reduction in the total quantity due to the loss of water, but there appears to be little alteration in the character of the blood, excepting a relative increase of the other constituents on account of its slightly inspissated condition. Observers appear to differ somewhat in their opinion as to the actual changes which occur. Von Noorden declares that the leucocytes are slightly diminished in number

and the alkalinity unaltered. The fatty content is increased because the tissue fat is being consumed and is conveyed to the fasting organs by means of the circulating blood. Sugar is always present in small quantities, because glycogen is constantly being formed, in the later stages of course from tissue protein, and the glucose in the circulation is the visible expression of its transportation from the liver to the muscles. The quantity of globulin is slightly increased in the blood plasma, no doubt owing to myosinogen being transferred from the muscles to become serum globulin.

On the other hand, other experimenters state that there is a progressive average fall in the number of erythrocytes, and an accompanying diminution in the percentage of hæmoglobin. There is also a relative progressive fall in the percentage of leucocytes, but the various types appear to maintain their relative proportion to each other. Most observers agree that there is a relative leucocytosis which would explain the high percentage of polymorphonuclear leucocytes and large lymphocytes and the relative low percentage of small lymphocytes.

The body temperature follows the normal variations, the average difference being $.5^{\circ}$ C. while fasting, instead of 1° C. when not. At the termination of Succi's forty days' fast at the Royal Aquarium his temperature was 97.4° F. On account of the combustion of the fat and tissue protein the temperature is well maintained, rarely falling more than 1° F. until the end of a long fast, when it gradually sinks, and a few days before death rapidly falls, because the supplies are exhausted and the heat-regulating functions destroyed. All fasting subjects complain bitterly of the cold, and if they can only be provided with a sufficiency of external warmth they will survive for a much longer period.

In all cases under the care of skilled observers the pulse rate, volume, and strength notably decreased, as might have been expected, but upon the slightest indulgence in exercise the pulse rate was accelerated to a point much higher than the normal. Zuntz, in his observations in Cetti's case, remarks, "One can assume that during fasting, in consequence of the ease with which the heart is fatigued, exhaustion will readily make an end of the possibility of doing work before any accessory muscles can be called into play."

Despite this statement, however, and although the loss of strength is usually progressive, it is not always so. On the twelfth day of Succi's thirty days' fast he rode for an hour and forty minutes on horseback, walked some distance in the evening, engaged in a racing contest for eight minutes against three students, and finally had a bout of fencing, taking in all 19,900 steps during the day. Again, on the twenty-third day he visited the theatre and indulged in fencing bouts with swords, the number of his steps on this occasion amounting to 7,000. All this work, however, was insufficient to increase the excretion of urinary nitrogen beyond the usual amount, but was accomplished by an increased metabolism of fat.

The blood-pressure is always reduced.

Effects on the Digestive Organs.—In common with all the secretions, the saliva is diminished in quantity even when plenty of water is taken, and it frequently becomes acid in reaction. The diastatic ferment is lessened in the mouth, although it can often be isolated from the urine. This, of course, may be produced by the pancreas as well as the solitary glands. In consequence of these changes in the buccal secretions the tongue is somewhat coated, but it is rare to find the heavy coating gradually increasing as the fast progresses, a statement related in connection with those who deprive themselves of food in an effort to cure disease. As most of such cases are subjected to frequent rectal injections it may be surmised that such a foul tongue is an evidence of absorption of toxins from the colon, and the spontaneous clearing of the tongue which is held to be the psychological moment for terminating a long fast may indicate exhaustion of the stored up fat and an increase of acidity due to relative excess or accumulation of amino-acids in the system.

At all events, the administration of food which will call forth the various secretions is sufficient to effect a speedy clearance. Hence it is that milk, which requires no saliva for its digestion, produces a coated, furred tongue, whereas an ordinary diet, especially if vegetable acids such as pineapple juice are included, soon succeeds in dissolving the thick coating. There is no evidence to support the statement made by laymen that it is dangerous to break the fast at any

moment. Fasting in the main is really a painless procedure, because, after the first day or so, when a feeling of hunger may manifest itself at meal times, there is no discomfort, and in many cases there is no desire for food even when permission to eat has been obtained. This is an interesting and significant fact, indicating that the appetite is not so much an expression of cell hunger as the result of a local condition of the alimentary canal inciting the individual to regular replenishment. Excessive depletion of the cells interferes with their ability to intimate to the local centres in the mouth and stomach that nutriment is required, and hence there is no appetite.

The secretions of pepsin and hydrochloric acid are both diminished to vanishing point, but the power of immediate secretion in response to the stimulation of food is retained. The unutilised pepsin, or it may be pepsinogen, is frequently absorbed and may be recovered from the urine.

The bile is diminished in quantity, but this is largely due to lack of fluid, because it is decidedly more concentrated. The store of glycogen is rapidly used up at first, but more slowly thereafter. It is, however, capable of being formed anew, and the stores replenished even during fasting.

Fæces continue to be formed and starving animals defæcate at least every two or three days. They are composed of the unabsorbable part of the digestive juices, such as cholesterin, bile pigments, mucin, disintegrated epithelial cells from the intestinal mucous membrane, and to a large extent of bacteria. The frequency of evacuation of the bowels varies in man, as in the lower animals. Zuntz records that during a short fast Breithaupt had two motions in six days, well formed, soft yellowish brown, showing under the microscope needle-shaped crystals of fatty acids embedded in a finely granular amorphous substance, in appearance, indeed, similar to those passed on a diet of meat. In this case the average daily quantity amounted to about 9.5 grams, but in other cases an average of 22 grams dried fæces has been reached. The reaction was acid and hydrobilirubin was present. This is quite in accordance with expectation, because hydrobilirubin is simply the refuse of hæmoglobin, which continues to be disintegrated even during starvation.

Little albumin is present, but there is a relatively large proportion of nuclein. The nitrogen-content varies from .113 to .316 gram daily with from .44 to 1.35 gram ether extract and .25 to .48 gram ash. The fat is composed partly of free fatty acids and soap and partly of neutral fats and cholesterin. The power of absorption is not diminished during fasting, or even during chronic malnutrition, and putrefaction still goes on, although no protein reaches the colon except what is contained in the epithelial detritus, the inspissated intestinal secretion, and an occasional little hæmorrhage which takes place from the bowel wall. The species of bacteria which predominates will determine the nature of the end-product. If the proteolytic bacteria be in the ascendant, indol and skatol will be formed, and it is important to note that these do not come from the breakdown of tissue protein. On the other hand, phenol and skatol will be present if saccharolytic bacteria abound.

Auto-intoxication is therefore quite possible during fasting, and may account not only for the coated tongue but for the presence of indican in the urine.

INFLUENCE OF FASTING ON THE URINE

The average quantity of urine is usually subnormal, even when large quantities of water are consumed, and is generally 300 c.c. less than the amount consumed. The loss of water by the lungs, skin, and kidneys exceeds that ingested, due to the fact that water is being manufactured through the tissue breakdown. The reaction is acid, and becomes increasingly so from day to day, because of the formation of sulphuric, phosphoric, oxybutyric, diacetic, and uric acids. The specific gravity varies, sometimes being below normal.

Less than the normal 85-88 per cent. of urea is formed, and more than the normal 2-5 per cent. of ammonium. This is accounted for by the formation of the above acids by tissue disintegration, and as there is not enough fixed alkali with which they may combine, they enter into union with a part of the ammonia which is formed by decomposition of the protein, and so the formation of urea is prevented.

It might be thought that fasting was a favourable oppor-

tunity for ascertaining the precise quantity of endogenous uric acid, but it is to be remembered that the organism is chary of using the nuclein from which purins are formed, and hence much more is manufactured on a full diet than during starvation. Besides this, some of the purin bodies produced by decomposition of nuclein are converted into urea, and one must not forget the possibility of the synthetic production of uric acid, or the small quantity formed from the hypoxanthins of muscle. A ready method of estimating the nuclein decomposition is to combine the purins with the phosphoric acid excreted; but this is not available here, an accurate result being impossible on account of the large excretion of phosphoric acid due to the breakdown of bone.

In addition to carbon dioxide, water, sulphates, and urea, creatinin is now recognised as one of the products formed from the disintegration of proteins. Under normal conditions about 1 gram of creatinin is excreted in twenty-four hours, the exact amount depending upon the nature of the food. Folin has shown that the absolute amount of creatinin eliminated in the urine on a meat-free diet is a constant quantity, differing in individuals, but quite independent of the quantitative changes in the total amount of nitrogen excreted. The amount, indeed, is fairly constant from hour to hour and from day to day. Although its formula, $C_4H_7N_3O$, is comparable with that of creatin, $C_4H_9N_3O_2$, minus one molecule H_2O , it is not derived from the creatin of the muscular tissues of the organism nor from muscle ingested as food. It has been supposed that it is the expression of some special metabolic process in muscle, a process upon which the efficiency of muscular activity may depend.

Creatin is not present in normal urine, but is present in the urine during starvation, in acute fevers, in women during involution of the uterus, and in conditions where there is rapid loss of muscle. Its fate in the normal body is unknown, although it is conjectured that it may be converted into urea, yet creatin injected into the blood does not follow this course, but undergoes excretion as such. Creatinin excretion is quite independent of diet and exercise, and Folin believes that it is the expression of the extent of endogenous metabolism and is manufactured in the liver and not the muscles.

Mellanby, again, has shown that it is not present in muscle at all, even after prolonged work, and advances the hypothesis that the liver manufactures creatinin out of certain products of protein katabolism; that these are carried to the muscle, combining with water, thus forming creatin; and that when saturation has taken place, excess of creatinin is then excreted by the kidneys.

In fasting, creatinin is undoubtedly diminished proportionately to the lessened tissue disintegration.

The mineral salts are likewise excreted proportionately to the tissue breakdown. They are unable to remain in the circulation, as the kidney is ever on the watch to remove any excess.

The chlorides in the urine, being chiefly derived from the food, are diminished in quantity more than the other salts, because the tissues contain very little sodium chloride. Normally there should be in the urine one part NaCl to two parts urea, and the daily excretion of NaCl should amount to about 12 grams. If several grams be found in the urine during fasting, it is being derived from ingested food or drink, as the tissues could not supply so much. Cetti on the tenth day excreted .6 gram, Breithaupt on the sixth day .35 gram, Succi on the tenth day .51 gram, which was reduced to .36 gram on the eleventh day.

On a normal diet the ratio sodium : potassium :: 64 : 36 obtains, but the proportion of potassium may be much increased by eating a large quantity of flesh which is rich in that salt. During fasting, the muscles and glands which supply the nutriment being rich in potassium and poor in sodium, the ratio is reversed, more potassium than sodium being excreted, and this is a fairly absolute proof of genuine complete fasting. On the seventh day Cetti excreted 2 grams potassium and only .7 gram of sodium, whilst on the eighth day Succi excreted 3.7 grams potash to 1.9 grams of sodium.

The relation of phosphorus to nitrogen in muscles and glands is 6.6 : 1, but this proportion is reduced in the urine of starvation, because a larger relative amount of phosphorus from the breakdown of bone is excreted.

More magnesia than lime is excreted in the urine of a normal man, because animal food and most vegetables are

poor in lime and rich in magnesia. In fasting, an increase takes place in the excretion of lime, because bones contain more lime than magnesia, and because it is cast off by the kidney instead of by the bowel, as in normal cases. This is accounted for by the fact that the fæces are deprived of the lime that would be ingested in the food, and the presence of abnormal acids in the blood helps to dissolve more lime salts, and so they are excreted by the kidney.

The urine of fasting people always contains acetone bodies, both acetone and diacetic acid and even β oxybutyric acid being detected on the second day. It is now well recognised that acetonuria depends on a diminished supply of carbohydrate food and a proportionate decrease of the carbohydrates decomposed as compared with the fat destroyed. In Cetti's case, before the fast, only .075 gram acetone could be discovered in the urine, and in Breithaupt's urine the amount was too small to be capable of estimation. On the tenth day of Cetti's fast, however, .671 gram, and on the sixth day of Breithaupt's fast .506 gram of acetone appeared in the urine. Acetone is usually excreted by the breath, but during fasting it appears almost entirely in the urine. On the second day after the termination of the fast in both the above-mentioned cases the urinary secretion reverted to the normal condition, showing the sensitiveness of the body to a supply of carbohydrates.

Illustrative Case.—The most complete study of the phenomena of fasting in this country with which I am acquainted was conducted by Dr. E. P. Cathcart on Victor Beauté, a German professional starving man or "hungerkünstler." The fast lasted for fourteen days, and the following is an epitome of its effects. The tongue was fairly clean throughout. The loss of weight amounted to .85 gram per cent. daily; but the loss of strength was not notable, as Beauté was able to carry two 56 pound weights at arm's-length for some distance on the last day of the fast. The pulse dropped on an average 15 per minute, the respiration rate was unaltered, the temperature became slightly subnormal, and the blood-pressure was lowered from 120 to 88 mm. Hg. The urine was reduced in quantity and its specific gravity lowered. Analysis showed that the total nitrogen was steadily reduced to the end of the fast, and the quantity of urea fell proportionately. A steady

rise of the ammonia nitrogen, compared with the percentage of the total nitrogen, was observed until the eighth day, and thereafter a steady fall.

The uric acid was fairly regular in its output, though it was slightly diminished in quantity as compared with the period before the fast. In contrast with this the total purins rose consistently till the close of the fast. There was a steady fall in the quantity of creatinin, and for the first time in such analysis creatin was discovered, although it gradually became reduced in quantity. There was a steady fall in the quantity of chlorides and phosphates, but a distinct retention of the latter was noticed after the completion of the fast. The total sulphur, inorganic sulphates, and ethereal sulphates steadily fell in quantity, whereas the neutral sulphur, whilst reduced, maintained a fairly regular output. The acidity fell the first day, rose the next two days, and thereafter declined steadily till the end of the fast. The calcium and magnesium both diminished, but the magnesium in greater proportion than the calcium, the ratio before the fast being $\text{Ca}:\text{Mg}::2:1$ —during the fast, $\text{Ca}:\text{Mg}::3:1$.

Before the fast more sodium was excreted than potassium, but during the fast the situation was reversed, the ratio of excretion on the third day being $\text{K}:\text{Na}::1.5:1$, and on the seventh day $\text{K}:\text{Na}::7:1$, but after the fast the normal condition of affairs was restored. Acetone and aceto-acetic acid both appeared in the urine during the fast, but disappeared after its completion.

Additional observations were made in the same case by Dr. F. J. Charteris, chiefly with reference to the blood changes. He noted that although Beauté slept quite soundly he was troubled with dreams in which he was feasting at a banquet of various delectable comestibles. He suffered much from cold, and was quite unable to keep warm. As the fast proceeded the pulse became slower, softer, and weaker, and the blood-pressure fell quite 25 per cent. The amount of hæmoglobin diminished from day to day, but with this exception the composition of the blood was hardly altered, although there was a tendency to leucocytosis. Neither the opsonic index nor the composition of the serum was altered in any degree.

The actual cause of death from starvation has given rise

to a good deal of discussion. It cannot be due to any radical alteration of the cell structure, because chemical analysis has failed to detect any. Nor is it to be attributed to a general failure of all the cells, because then death would occur whenever a certain percentage of their protoplasm has been decomposed. This, however, is not the case, and more protein indeed may be lost from the muscles of a spawning salmon than is usually found in animals which have died from starvation. The hypothesis which best meets the case is that of E. Voit, who considers that it is due to a loss of substance in the organs important to life, although it may also arise owing to deficient nutrition of these organs.

It is important to note that once it has been lost protein is none too readily replaced. After a prolonged fast recovery is a slow affair, and very special dieting is necessary if the best results are to be obtained in the shortest space of time. Subsistence on a diet of insufficient caloric value is "economically" unsound, and if we are to maintain our supremacy as the leading industrial nation of the world we must take steps to ensure the adequate nutrition of our working class population. Rowntree, in his investigation of poverty, points out that amongst the lower classes in Philadelphia, U.S.A., each individual consumes on an average 110 grams protein daily, as compared with a daily consumption of only 90 grams protein per head in York. Although doubtless other factors must be taken into consideration, he considers this defective feeding as the most important item in the production of a lower standard of health in York. He subdivided the population of York into three classes, according to their financial position, and ascertained that amongst the lowest class the average height of boys of thirteen—the age when they left school—was less by three and a half inches than the height of the children of the upper classes, whilst the average weight of the same boys was 11 pounds less than that of boys of a similar age in the upper classes. Of the children of the lowest class, 2·8 per cent. were mentally deficient, as compared with only 1·3 per cent. of the children of the better classes. Whilst it is impossible to eliminate altogether other deleterious influences in accounting for this lowered standard of health and growth, these statistics are quite on a par with

those obtained by Major C. D. McCay in Calcutta, in which case there was no question of the introduction of any disturbing factors, save that of an insufficient diet.

HARMFUL EFFECTS OF THE FASTING FAD

Laymen are too much accustomed to give vent to all sorts of prophetic utterances as a result of their single experiment on their own bodies, forgetting that not even a skilled observer can be trusted to determine the true significance of his own symptoms. Quite recently the author of a sensational book on the stockyards of Chicago fasted for twelve days, and on the strength of the loss of a headache on the third day of the fast and his perfectly ravenous desire for physical and mental work when he resumed a milk diet, set the fashion for a renewed outburst of fasting for the cure of ill-health. How many people died as a result of this craze it is impossible to say, but the daily papers certainly recorded more than one death distinctly attributable to the effort to emulate his ill-timed experiment. Dr. Saundby, in the *British Medical Journal*, states:—

“That this is no imaginary danger is proved by three fatal cases which have come under my notice. The first, a motherless girl, the daughter of a busy doctor, was treated in Dr. Playfair’s home, returned home, was not supervised, and died. The second was a woman under the care of an old practitioner who refused to believe in the risk; she also died. The third was a young man whose nurse neglected her duty, and after his death food supposed to have been eaten was found concealed everywhere in his bedroom.”

The inmate of a prison or a lunatic asylum who refuses to take his meals is fed by compulsion; the trained scientist who subjects animals to a period of enforced fasting without a Government license (and in Great Britain this is practically always withheld) is subject to the severest of penalties; but the irresponsible member of the public who, for the sake of notoriety or in obedience to impulse, impels misguided human beings by his example to play with their lives, is immortalised by the public Press and placed on a pedestal scarcely less prominent than that of the greatest benefactors

of humanity. The entirely unwarranted statements of such individuals are quoted with such a show of authority that people whose mental balance is impaired by ill-health are instigated "to expel the food poisons which have accumulated in their body, as well as throw off the poisons of any disease" which may attack the system, by a method whose right to a place in therapeutics has not yet been vindicated.

It is cruel to suggest to the victims of inanition due to the ravages of consumption and other diseases of malnutrition that further depletion of their vital resources will be attended by remedial results. Surely the days of famine in India, Ireland, and elsewhere have provided a sufficient number of involuntary examples of fasting and the diseases directly dependent thereupon, to demonstrate the perils of the practice, especially when carried to excess by one already exhausted by the inroads of serious disease. Whether in health or disease it is an indubitable fact that during a fast the body lives at the expense of its own substance. The organs by which the greatest amount of work is done are the least encroached upon and maintain their integrity for the longest period—which means that they work not at the expense of their own substance but of that of the less vital organs. E. Voit fed pigeons on an acalcic diet, and after death the bones which had least demand made upon them, such as the skull and the sternum, were found to be brittle and perforated, whereas the bones of the active parts of the body, such as the legs, were strong and well-developed. It has also been pointed out that the Rhine salmon lives in fresh water for from six to nine months without indulging in food, and that the muscles are used up in order to feed the reproductive organs. But in the end even the vital organs must contribute their quota to the general demand for nutrition, and when they are exhausted death supervenes. Therefore, although the brain and nervous system resist the demands for a lengthened period, it is a mistake to say that they can exist without nutriment. Fasting, indeed, in no wise implies abstinence in the true sense of the term. It is simply a change of diet, the body living on its own tissues instead of on vegetable or animal tissue.

The assertion also that only the excess of nutriment or

accumulation of morbid waste matters is destroyed during a long fast is essentially erroneous, although it is true that during the first few hours after the last meal a sufficient amount of ingested food substance will be available without any drain upon the tissues themselves. The simile which best fits the fasting man is not that of a furnace whose bars are choked with ashes and whose flues are clogged up with soot, so that a general conflagration is welcome to clear away the obstruction in order to produce more effective combustion. It is rather that of a furnace which has disposed of its extraneous combustible material and proceeds to attack the furnace bars and flues, and even the very boiler plates themselves, so that an explosion is imminent. Nor is it possible that the waste matter can be lessened in any appreciable degree, because waste is formed whatever fuel is used, and the so-called clogging of the tissues is all the more certain because the organs of excretion are themselves weakened on account of their necessary contribution to the nutritive demands.

It is hardly fair to conclude this chapter without referring to the modified form of fasting coupled with purgation championed by Dr. Guelpa, of Paris, as a therapeutical procedure of great value. He is evidently obsessed by the doctrine of auto-intoxication, for he protests against the recognition of emaciation as an unfavourable sign or of weakness as a sign of deficient nutrition, encouraging the presence of the former as a means of ridding the system of toxins and maintaining that the latter is an indication of their imperfect removal. Hunger he considers an expression of intestinal auto-intoxication, as it can be appeased by repeated purgation, and boldly declares that death from starvation is never due to insufficient tissue repair, but to an accumulation of toxins. Manifestly this is a frank confusion of appetite and hunger, and there is nothing very new in his practice, except its details. It is simply a revival of the method of depletion familiar in the days of bleeding and antimony presented in a new guise, for although it may be frequently repeated in the course of many months, the purgation is not a daily procedure and the fasting never continues at the outside for more than a few days at a time. The cases of diabetes and gout which

are cited as having been cured by the treatment are evidently typically sthenic, and doubtless because of careful selection he is able to announce that this method of treatment is never harmful, nearly always useful, and sometimes gives truly marvellous results.

Whatever be the value of a few days' fast, subsequent to a food debauch interposed occasionally in the regimen of diabetes, or preliminary to an effort of hyperalimentation, I am quite certain that the risks of a prolonged fast are out of all proportion to the anticipated advantages. Nay, I would go further and say that there are absolutely no benefits which can be obtained from even a very short fast that cannot as certainly accrue from a moderate restriction of the diet within reasonable limits, and that the dangers associated with a prolonged fast can only be combated by a powerful and vigorous constitution.

CHAPTER XVI

CONCLUSION—THE PRACTICE OF MODERATION

To one who has closely followed the arguments for and against the various dietetic systems described in the foregoing chapters, very little reflection will suffice to reveal the only principle which is of universal application in the selection of a diet. It is obvious at the very outset to the scientific mind that there can be absolutely no justification for the claims made by each set of propagandists for the wholesale adoption of their tenets and practice, because the personal factor which is of such vital importance in all human affairs is overwhelmingly so in the question of diet.

Diet and Character.—It has been held that popular taste is an infallible indicator of the best and most suitable nutritive items in a nation's bill of fare, and doubtless there is a period in the history of every country, before it has emerged from its primary isolation and come into contact with other nations, when this may be true. In such circumstances the selection of food is dictated less by choice than by necessity, and as the resources of most countries are strictly limited—and this remark applies with especial force to the most robust and vigorous peoples living in temperate climates—the choice is by no means boundless. It has been claimed that racial features have thus been moulded, and that the character of a people owes its origin in great measure to its food. But there is absolutely no authority for the statement that the character of a man is influenced by what he eats. The North American Indians, who lived to a large extent on flesh, were fierce and warlike, while the Eskimos, who live entirely on flesh, are amongst the mildest and most peaceable of men.

The Armenians are periodically massacred by a race of blood-thirsty vegetarians. The Hindus, who live on rice, are lacking in stamina, while the Japanese and Chinese, who are also stated to live on rice, are about the toughest and most enduring of mankind.

Diet does not alter the character or personality, but in large measure the personality decides the most suitable diet. The facility of communication, too, which has been such a potent factor in the history of the world during the last century, has altered in a marked degree the dietetic habits of mankind—no doubt originally dictated by climatic necessities—and has interfered in a large measure with any reliance which might have been placed on the popular taste as a guide to the most suitable food for any nation. The comparative cheapness of meat and of such beverages as tea has tended to their enormously increased consumption, and now they are at the command of even the very poorest people. It cannot be said that tea, coffee, cocoa, and tobacco have in any way increased the efficiency or contributed to the health of the community, and it is now recognised that they are not only luxuries, but in most cases unnecessary and probably always harmful.

Legislation has recognised this, and by taxing them has no doubt been of some service in limiting their consumption; and one might go so far as to say that if it could be demonstrated that meat is likewise harmful, because liable to be used in excess, it should also be taxed. Our recent experience of the diminished consumption of alcohol by reason of its increased taxation has been a valuable lesson to our legislators, and it may be hoped has opened their eyes to the philosophic fallacy of "free food" in our present stage of evolution.

Review of Diet Reforms.—It is not altogether easy to give any rational explanation of the origin of the various dietetic sects in existence—although I will presently indicate my view in the matter—and an attempt to reconcile their doctrines with any fundamental code of reasoning will apparently meet with as little success.

We shall begin our comparisons of their various advantages by considering first the three main theories dealing with the quantity and quality of the one absolutely essential alimentary principle, viz., protein.

The low-protein feeders admit flesh into their dietary, have not the slightest objection to purins in soups or xanthins in tea, coffee, &c., and lay no special stress upon the observance of other laws of health, such as the necessity for exercise, abstention from tobacco, &c. If they yield obedience to any rule of life, it is in their endeavour to see that their diet contains a sufficiency of fats and carbohydrates to satisfy the caloric necessities of the body, and in large measure to leave the protein to take care of itself.

The purin-free feeders expunge all purins and xanthins from their diet list, and are most sedulous in their insistence upon at least 50 per cent. more protein, while one would be disposed to infer, from reading the published treatise of their leader, that these are the only practices essential to perfect health.

The flesh-abstainers agree with the low-protein advocates in the smallness of their protein-content, and with the purin-free feeders in their objection to purins and xanthins, but in addition to this expunge every possible toxin from their diet list, and place the greatest emphasis on the performance of every known law of health. It is the irony of fate that in their efforts to adapt vegetarian foods to the palates and digestions of their devotees they should have enlisted art to such an extent as to have deprived many of them of their most valuable qualities. They have concentrated their attention so closely on improving their digestibility by removing much of the indigestible cellulose, that they have been compelled again to call in the aid of art to supply the deficiency, and we are thus presented with the spectacle of the vegetarian eating highly concentrated artificial foods and supplementing them by adding the lost cellulose in the form of blocks of agar-agar. It may be said with much truth that a lack of cellulose is the prevailing defect of the food of civilised mankind, and is responsible for most of the chronic constipation so rampant to-day, but a system claiming to provide the "natural" diet of man should surely be free from this defect. It will always be found that any disturbance in the balance of a diet, even if it does not interfere with nutrition, is liable to upset the natural rhythmic action of the digestive organs and so disorder the secretions or in some other way induce defective functioning.

Moderation the only Common Factor.—The one thing upon which these three sects agree is in the diminished amount of food, and so the only conception which appears to unite them is the fundamental doctrine of moderation, which has not only been taught from time immemorial, but is actually practised by all sensible men at the present time.

But a close examination of each of the minor systems propounded will disclose the fact that in addition to, or because of, its other more specific features, the principle of moderation is the most valuable factor it possesses. Reviewing them *seriatim*, we note that the doctrine of hyperpyræmia was enunciated by its author less as a diet for everyday life than as a therapeutic agency in the treatment of various neuroses and chronic recurring maladies; but nevertheless its prominent characteristic is a notable reduction of the carbonaceous principles as well as of the total caloric value of the food. The advice is also proffered that not only will this dietetic restriction be found of value during an attack, but that if it continue to be practised with intelligence there will be infinitely less chance of the supervention of any further attack of the disease which necessitated the treatment.

The very designation salt-free diet is suggestive of restriction in the daily menu, and to most people deprivation of even the added chloride of sodium would necessarily be associated with a lessened appetite, and therefore a diminished consumption of food. The same significance would not perhaps apply to the acalcic diet, but one who is compelled to subsist on lime-free food has by no means a wide range of choice and must perforce content himself with a very limited menu. Even where the addition of salts is advocated, as in Lahmann's system, it is only because he assures us that a more accurate measurement of the items of our daily diet is a necessity. The deprivation of animal food which he advocates unduly interferes with the proper balancing of the ration, and so compels the addition of artificial salts to supplement the otherwise inefficient amount of nutriment in the dietary. Provision of the appropriate quantity and proportion of mineral salts in the daily bill of fare enables the nutritive requirements of the body to be satisfactorily discharged on a smaller supply of food.

The increased potations of water consumed at the various spas are only necessary because of the too liberal allowances of victuals which most of the victims have consumed since their previous visit, while on the other hand limitation of the supply of drinking water or other fluid is necessarily accompanied by a diminished appetite. But in both these methods of dietetic procedure a severely restricted allowance of food is carefully counselled.

Efficient Mastication of Vital Importance.—The practice of efficient mastication is undoubtedly the best means of enforcing reduction in the total amount of food, as well as of the protein, and is probably its chief value. For where moderation is practised it is perhaps of less importance that such meticulous attention should be paid to the comminution of every particle of food. It is impossible that mastication, however effective, can increase the caloric or building value of flesh protein, and even if it be conceded that Fletcher could live on less than 60 grams, it is always a blunder to argue from the special to the general. It is quite a pertinent question to inquire whether excessive mastication, *i.e.*, the conversion of a meal into a mere mechanical exercise instead of a social and gustatory pleasure, may not in the end threaten the human family with great dangers of insufficient nutrition.

Mastication is of prime importance in assisting in the conservation of the teeth. Dentists are agreed that an excess of soft foods, such as starchy and saccharine materials encourages caries, and, however skilful they may be, their mechanical attention can never supply the place of coarse food. Another important function of slow mastication is the opportunity afforded of well mixing the food with a sufficiency of air and so encouraging the growth of aërobic and discouraging that of anaërobic bacteria, thus aiding in the limitation of putrefactive toxins.

Whatever value there be in the fashionable curdled milk treatment is chiefly bound up with the diminution in the consumption of animal food, and the necessary restriction of other less innocent fluids, such as tea, coffee, &c.

The purity of yeast-free bread and other similarly prepared eatables is hardly compensated for by their unattractiveness,

and it is scarcely a form of diet which would encourage an excessive consumption, because of the careful mastication necessary, whilst one of the tenets of the raw-food advocates is to avoid the "vast bulk" of devitalised stuff contained in cooked foods and depend for nutrition upon the attenuated proportions demanded by uncooked foods.

The no-breakfast plan is ostensibly a method for the deliberate enforcement of a restricted diet, although there is always a possibility that it may defeat its averred purpose by the rigorous mode by which it proposes to achieve its object.

Fasting is the principle of moderation carried to absurd lengths. No doubt it is of great temporary value in the treatment of acute disease where, by reason of the importance of over-anxious relatives, the unfortunate patient is frequently subjected to deliberate overfeeding. As I have already shown, it is usually a most dangerous procedure in chronic disease and almost always attended by serious risk. The fact that professional starving men—"hungerkünstlers"—sustain so little damage from their severe ordeal is a great tribute to their physical powers, and should not serve as a model for the encouragement of neurotics to attempt a similar procedure, even although they may occasionally escape scathless.

Forced feeding is only apparently an abrogation of the principle of moderation, because its adoption as a therapeutic measure in severe cases ensures the certainty of a more thorough utilisation of the items of nutrition and hence greater economy in their use.

It will thus be manifest that apart from their suitability in individual cases the only apparent virtue common to all these systems is that of moderation, which we have seen is the principle underlying the major dietary systems previously considered.

But the average man will be very much surprised if he will sit down and carefully estimate the caloric value of his day's food. He will most likely find that it is very much below the 40 calories per kilo, amounting to over 2,500 calories per day, allowed by von Noorden, to say nothing of the 3,000, 4,000, and even 5,000 calories mentioned by some

other authorities. I have frequently estimated the caloric value of my own diet, and have sometimes been depressed because I could not get it to exceed 1,800 calories. I have been much comforted, however, to discover in a little book by Max Einhorn on diet and nutrition that his own average was 1,650, or 32 heat units per kilo, and this was on a mixed diet, which, he informed me, he was profoundly convinced was the only rational dietary for a healthy man. Probably most men conform more closely to the low-protein diet than they are willing to admit. All old men attribute their longevity to great moderation in diet, and especially to a minimum allowance of meat, the great stimulating properties of which are not sufficiently recognised.

Diet and Idiosyncrasy.—A point of great importance too little emphasised by dietetic reformers is the undoubted existence in certain individuals of idiosyncrasy for certain articles of diet. Nothing more fully illustrates the truth of the old proverb, "What is one man's food is another man's poison." Manifold instances are recorded of people who could not eat fish, shell-fish, strawberries, honey, sugar, apples, eggs, meat, rice, figs, pears, and even wheat, without presenting disagreeable symptoms, which in more than one case where there was a hereditary predisposition have terminated in death.

In my opinion this constitutional peculiarity accounts for the origin of many of the cults. Trousseau somewhere has said that medical men are in the habit of prescribing for their patients that kind of food which best suits their own individual cases, and I am inclined to think that dietetic theories are often propounded by those whose metabolism is imperfect. The chemical physiology of digestion has claimed so much attention from observers that they have had little time to devote to the chemical pathology of indigestion. It is not sufficient to make a classification of the various enzymes in the alimentary canal and align them against the respective food-stuffs which they are known to attack. Digestion is more than mere chemical solution. It is doubtless true this is the first stage, but probably only because of the necessity to prepare for the future co-operation of bacteria. The perversions of metabolism will never be fully understood until a careful study has been made of the

end-products which exist in those who depart from the standard of health. We shall thus see both sides of the shield and be better able to estimate the true rôle of food in health as well as in disease. It may well be that, given a perfect knowledge of diet—the appropriate building material of the body—we may not only cure but actually eradicate disease, and thus fulfil the ideal function of the medical profession. The problem as to how best to increase the efficiency of the individual and the race is ever in the foreground of the best minds of the medical profession. Preventive medicine has already abundantly justified its existence by suggesting practical solutions of this problem, and we cherish the fondest hope that when we have accurately fitted the dietary habits to the true physiological requirements of the body we shall have provided a most potent factor in the struggle for health, strength, increased working capacity, and the possession of increased powers of resistance to disease.

I am indebted to a medical friend for the following very apt simile of the present relations of the medical profession with the public. He compares the doctors to a company of first-aid experts eagerly desirous of helping the community, and stationing themselves, fully equipped with the latest additions to the resources of their art, at the foot of a precipice where they may practise on any who are unwary enough to tumble over. Their true function, he avers, is to erect a powerful fence at the top of the precipice, which will effectually prevent such catastrophes and so remove the necessity for all the elaborate preparations at the foot. He is, of course, presupposing that the only hindrances on the road to ill-health are of a preventive and—he is inclined to believe—mainly of a dietetic origin, and that a perfect knowledge of the most suitable alimentary substances and the rules of health duly applied would eliminate disease. One can hardly assent to a proposition so restricted in its character, and it is perfectly certain that even if we were to take it for granted, the individual can hardly be ministered to in any other manner than that which obtains at present. But it is to the everlasting credit of the medical profession that not only has it emphasised the necessity for some such preventive policy, so far as it is possible without unduly

interfering with the liberty of the subject (and in this way done its very best to nullify its own existence as at present organised), but its warning voice is raised without cessation in the interests of personal health.

The question of variety in diet is one of profound importance. It is a matter of common observation that those who confine themselves to a monotonous diet, even although it is capable of satisfying the full caloric necessities of the body, are apt to lose weight and exhibit an ill-nourished appearance. This is more particularly noticeable when the feeding of one day is practically a replica of that on preceding days, and probably owes its origin to the fact that the alimentary canal, and for that matter the senses, do not receive a sufficient amount of stimulation, and therefore are not aroused into activity commensurate with extracting all the nutriment from the food. Pleasures of all kinds are apt to pall, and even agreeable dishes with the most pleasing of flavours soon cease to be regarded with acceptance, and lose their power of titillating the palate and nasal mucous membrane when they appear at meal times with unfailing regularity. The æsthetic susceptibilities are offended, and the appetite juice reduced to a minimum. It is a trite saying that "hunger is the best sauce," but probably monotony of diet is the only justification for the use of any kind of sauce. Yet it is a remarkable fact that even a fresh method of preparing the same kind of food makes an indubitable appeal to the appetite and is followed by a more thorough utilisation of the food.

Apart altogether from this psychological or reflex influence, there is another aspect of the question deserving of equal consideration. In all probability the most potent advantage of a mixed diet of animal and vegetable origin is the conviction that we are thereby assured of the inclusion of the varied elements essential to the formation of a well-balanced dietary. Restriction of the daily menu tends to deprive the body of ingredients absolutely indispensable to its welfare, as is well exemplified in the case of beri-beri. The importance of mineral salts to the economy is receiving due emphasis to-day, not only with reference to the actual quantity required, but likewise of the ratio of the various salts to the protein, carbohydrate, and fat of the diet.

We have thus concluded what does not pretend to be an exhaustive consideration, but only lays claim to be a fairly comprehensive survey of the most modern theories of dietetic practice. It includes all those theories which have engaged the attention of medical men and laymen for many years, but excludes many which have merely an individual application and ought to be classed as purely speculative rather than expository. Amongst such I can prominently recall the extraordinary practice of a medical man who was accustomed to insist that the stomach could deal with any kind of food, provided it was required to give attention to only one article at a time, and supported his belief by confining himself to the consumption of one single article at each meal. The astonishing circumstance was that he professed himself perfectly satisfied whether his two meals a day consisted solely of potatoes for lunch and milk for dinner or beef for the former and fish for the latter, but his premature decease from a mental ailment was probably a sufficient explanation of his erratic practice.

I do not doubt that most of the systems detailed may be made to answer the nutritive and dietetic requirements of everyday life for individual cases, and, as has been proved by experience, some of them may even be suitable for considerable sections of people. I do not think, however, that any one of them has succeeded in demonstrating its right to the proud position of the universal food of mankind in the temperate zone. I am personally inclined to favour the claims of the low-protein system as on the whole the most satisfactory solution of the dietetic problem, but probably more reflective people will acquiesce in the proposition that the healthy man can live on any system of diet by attention to moderation, regularity, and variety, but the unhealthy man must look to the dietetic expert to guide him in the selection of the best system or kinds of food to suit his case.

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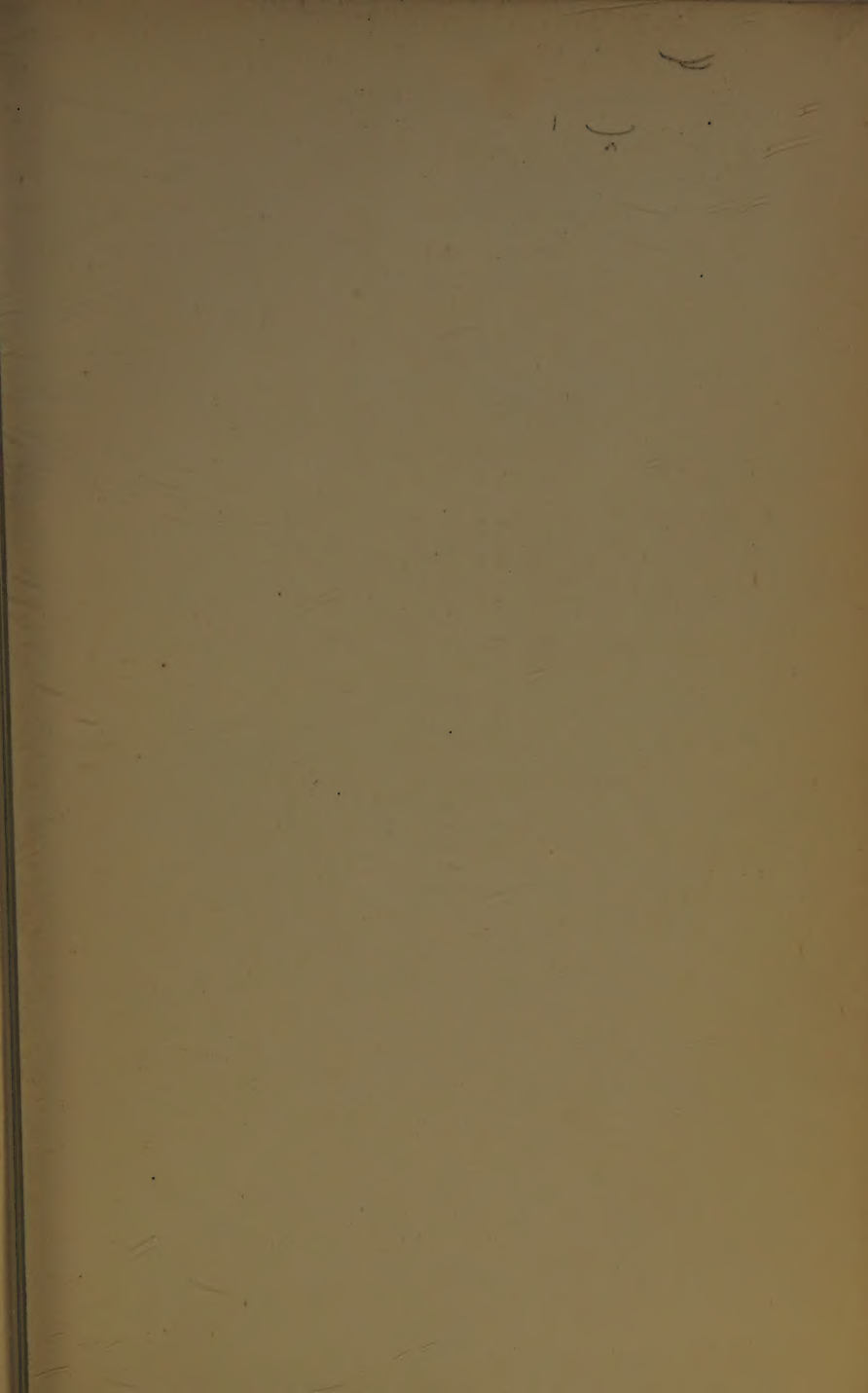
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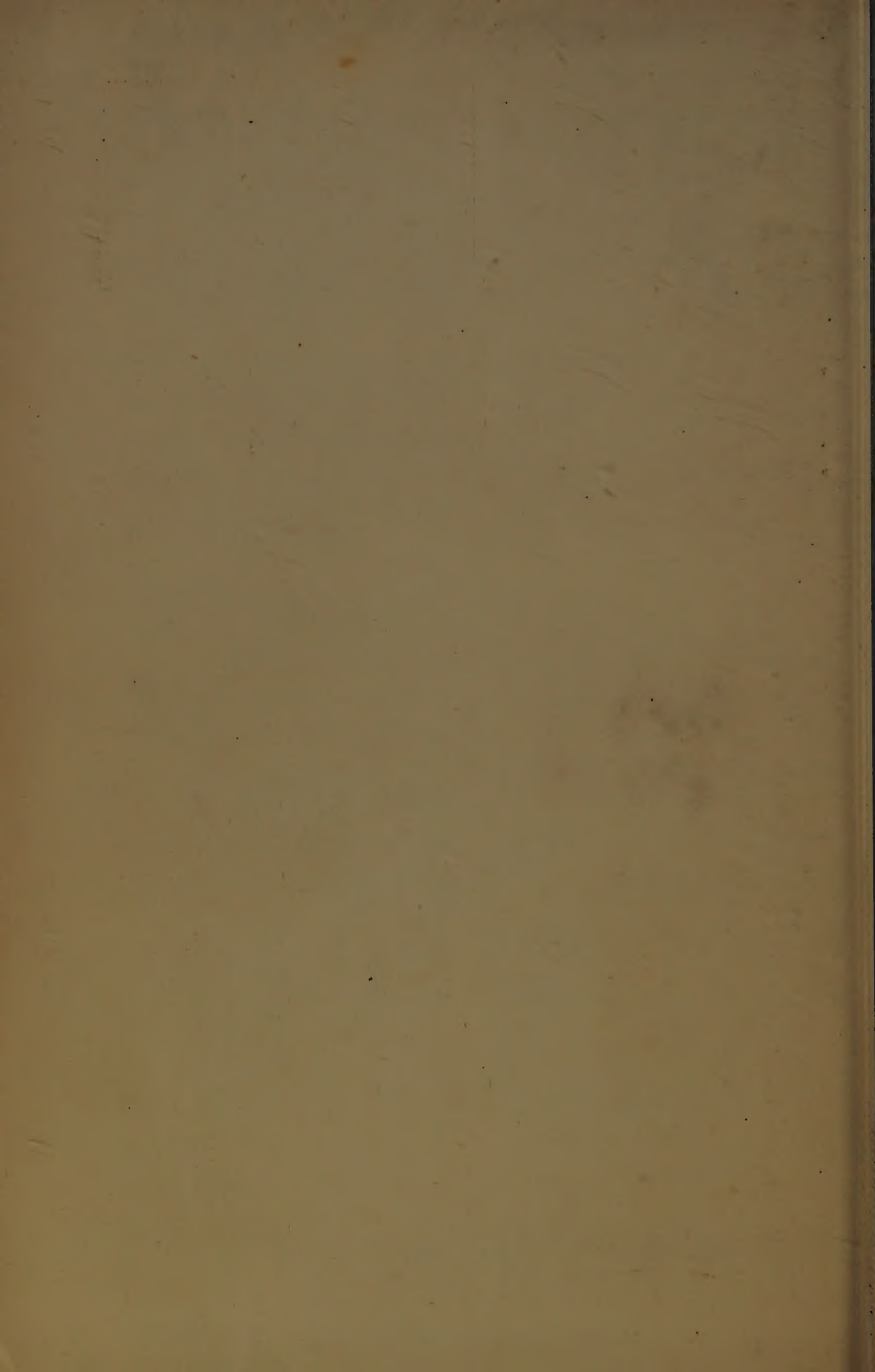
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